ADVANCES IN PRESERVATION OF DAIRY AND FOOD PRODUCTS

The Thirteenth Short Course

Organised under the aegis of Centre of Advanced Studies in Dairy Technology

August 13, 2001-September 12, 2001

Dairy Technology Division
National Dairy Research Institute (ICAR)
Karnal-132001
# CENTRE OF ADVANCED STUDIES in DAIRY TECHNOLOGY

## SHORT COURSE ON ADVANCES IN PRESERVATION OF DAIRY AND FOOD PRODUCTS  
13.08.2001-12.09.2001

## COURSE PROGRAMME

### 13.08.2001

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<td>Mr. D.K. Talwar</td>
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<td>11.30-12.15 PM</td>
<td>Visit to library</td>
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<td>Mrs. Savitri Jhamb</td>
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Dr. G.R. Patil

11.00-12.00 PM Communication skill for effective transfer of dairy processing technologies
Mr. D.K. Gosain

12.00-1.00 PM Internet and its relevance in dairy research
Dr. D.K. Jain
Dr. A.K. Sharma

Lunch Break

2.15-4.45 PM Estimation of antioxidants
Dr. Sumit Arora

29.08.2001

9.45-10.45 PM Active packaging- a new approach for shelf life extension of processed foods
Mr. A.K. Singh

11.00-12.00 PM Recent advances in dehydration of foods: Spray and fluidized bed drying
Dr. Alok Jha

12.00-1.00 PM Safety concerns for long life foods - Microbial resistance
Dr. S.K. Tomar

Lunch Break

2.15-3.15 PM Total quality management and HACCP system in dairy industry
Mr. K.L. Arora

3.30-4.30 PM Presentation by participants
Dr. R.R.B. Singh

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9.45-1.00 PM Combination drying of fruits
Dr. Abhay Kumar
Mr. A.K. Singh

Lunch Break

2.15-3.15 PM Retort processing for shelf life extension of foods
Dr. Alok Jha

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9.45-1.00 PM Determination of Fo value
Dr. Alok Jha
Dr. Sudhir Singh

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Er. Bikram Kumar

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9.45-1.00 PM Dehydration of paneer
Dr. Sudhir Singh
Mr. Ramswaroop

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2.15-3.15 PM Chemical preservatives in processed foods
Dr. Sudhir Singh

3.30-4.30 PM Presentation by participants
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## Packaging Technology in Food/Dairy Preservation

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## Pedagogy

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1.0 INTRODUCTION

Preservation is any purposeful treatment or processing of a food, which prevent spoilage and extends the keeping ability of a raw material to a period longer than its natural keeping quality.

During storage and distribution foods are exposed to a wide range of environmental conditions. Environmental factors such as temperature, humidity, oxygen and light can trigger several reaction mechanisms that may lead to food deterioration. As a consequence of these mechanisms, foods may be altered to such an extent that they are either rejected by the consumer or harmful to the person consuming them. It is, therefore, imperative that a good understanding of different reactions that cause food deterioration is gained prior to understanding the principles of food preservation.

The deterioration in foods may be caused either due to internal or external non-microbial biochemical changes, or due to microbiological changes in food.

1.1 Non-microbial biochemical changes

These changes may be either latent to be senses of consumer, or they may be discernible by the human senses.

The consumer cannot perceive latent changes visually, olfactorily or otherwise, and laboratory measurements are the only method to detect them. Still, the nutritional value of such materials may be seriously impaired. Such changes include the loss of sugar, varieties in the contents and composition of nitrogenous substances, and gradual oxidation and loss of vitamins.

Non-microbial changes in foods, perceptible to human senses, may often lead to serious deterioration noticeable to the average consumer. These include discolouration and changes in taste, flavour or consistency.

1.2 Microbiological changes

Most serious form of undesirable changes in perishable foods is the decay produced by various types of microorganisms. Substantial losses of nutrients occur in decaying foods, and considerable changes in external properties takes place in the material. Moreover, the decay makes the food repulsive and substances are
formed which are detrimental to the consumer’s health. Protection of perishable foods against microbial spoilage is one of the main tasks required of any food processor.

These possible changes in foods shows clearly that food preservation must be carried out taking into account the interaction between foods and a variety of environmental factors.

2.0 INTERACTION BETWEEN CONSTITUENTS OF FOODS

The chemical deterioration in foods is mainly caused by interactions between constituents of foods such as water, carbohydrate, protein, fat, minerals or vitamins.

2.1 Water as reaction medium

The most abundant constituent of perishable foods is water, whose availability is one of the pre-requisite for spontaneous reactions between rest of components. These components, normally present in amounts ranging from 5% to 30% in perishable foods, and rest is water. Water in foods is either free or bound in variety of ways to form various components or formations in foods.

Free water is an indispensable reaction medium where a great majority of chemical and microbial processes take place, altering food properties. The relatively high content of free water in perishable foods is one of the main causes of their perishability (Karel et al., 1975). The reactive substances are either dissolved or dispersed in some other manner; therefore the rate of their interactions is governed by the number of probable contacts occurring within a given time unit. The contact will be easier for substances present in higher concentrations in the medium, but there will be fewer contacts if the reaction medium becomes viscous and restrains the mobility of the substances. Desiccation or freezing out of free water from foods being processed and the crowding of the reactive components within a confined volume of the remaining solution may accelerate the adverse processes to some extent, but the increasing viscosity of the reaction medium, resulting from such treatments will delay the process at the same time. Which of these effects will prevail depends greatly on the degree of desiccation, temperature and specific composition of a food. Water may foster adverse changes directly when it decomposes for e.g. by radiolysis, or it may act as catalyst. The autoxidation of fats, however, is an exception; in this process no water is required for reaction to occur and if present it tends to inhibit the reaction. Water bound physically or physio-chemically plays practically no role in spontaneous changes in foods.

The major of mobility of water in foods and participation in microbial and non-microbial spoilage is normally water activity value (a_w). Essentially it is the ratio between the pressure of food vapours and the pressure of pure water vapours.

2.2 Sugars and their interactions

Saccharides are pyrolysed at elevated temperatures yielding strongly reducing and/or dark coloured products due to interactions between derivatives. The
so-called caramels resulting from this process, impart a poor appearance and bitterly
acrid after taste to foods and deplete them of nutritional value.

The reaction of reducing sugars with amino acids, known as Maillard reaction,
is the cause of non-oxidative or non-enzymatic browning of foods. Maillard reaction
often leads to the breakdown of flavouring substances, to the slightly acrid off-
flavour, to an increase in reducing efficiency of foods on heating, and to a loss of
certain portions of essential amino acids.

2.3 Lipids and their changes

Lipids act as reservoir of highly concentrated energy and several of them
contain indispensable nutritional factors - the unsaturated fatty acids. Their
importance for preservation lies especially in that they are open to various
undesirable changes which may cause fats themselves to deteriorate as well as
some other food constituents, thus impairing overall nutritional & sensory value of
foodstuffs. Three types of deterioration are encountered in fat: de-esterification,
saponification and oxidation.

De-esterification of fats in moist, still enzymatically active foods, is usually
catalysed by lipases-either native or of bacterial origin, and cause off-flavour in
foods.

Saponification alone of fats frequently leads to an objectionable taste and
odour changes in foods. Properties of non-fat components may also be affected e.g.
denaturation of proteins.

Oxidation of fat is one of the most important deteriorative reactions in food
that severely impair nutritive and sensory value of foods.

2.4 Proteins and Products of their degradation

Denaturation of protein; proteolysis; protein-protein, protein-carbohydrate,
protein-lipid, and protein-mineral interactions are important in food preservation as
these changes in protein may affect nutritive value and sensory quality of foods.

Denaturation of proteins produced by normal heating to less than 100°C is not
in itself detrimented to the nutritive value and sensory quality. Heating above 100°C,
however, result loss of lysine, methionine and cysteine.

Above 100°C, amino acids interact with sugars and with oxidized lipids
causing destruction of lysine. Interaction of proteins with Fe$^{3+}$ imparts the blue green
discolouration in boiled eggs.

The products of proteolusis take part in the interactions either as taste former,
as toxine nutrients for undesirable as well as useful microbes.

The protein-protein interactions are often beneficial and important for
preservation. For instance, sulphydryl group released as a result of protein-protein
interaction may reduce the oxidation of fat.
3.0 PRESERVATION METHODS

In devising the methods of protecting foods against microbes causing decomposition the processor is guided by the fact that the intensity, \( R \), of decomposition, in a particular environment, is directly dependent on the violence and concentration of microbes, and inversely proportional to the unfavourable conditions or resistance of the environment. This relationship can be schematically expressed, as an analogy to the classical formulation by McGullock (1936) as follows:

\[
R = \frac{\text{Microbe count virulence}}{\text{Resistance of environment}}
\]

If the value of the denominator is exceedingly larger than that of the numerator, the decomposition may be slow and imperceptible, or no decomposition at all will take place. The fraction also shows that not all the food-contaminating microbes are allowed to propagate and cause decomposition; the ratio of the factors is important and determines whether a food yields to or withstands the invasion of microbes.

In preservation practices the methods applied are either designed to diminish or completely suppress the factors given in the numerator, or support the factors given in the denominator.

Referring to the foregoing, practical methods used in food preservation can be classified as follows:

3.1 Removal of microbes from the medium

3.1.1 Reduction of microbial contamination of foods

These measures include any treatments in which the count of dangerous microbes is reduced as a preventive measure. These measures include

- cleanliness of tools and work stations
- cleanliness of air
- cleanliness of water
- cleanliness of auxiliary materials and additives
- hygiene of personnel
- disinfection of egg shells and prevention of invasion of microbes into the egg by placing the eggs into suitable environments, e.g. water-glass solution.

3.1.2 Removal of microbes from foods during processing

This category of measures includes processes in which impurities, or, as in liquids, insoluble components (sludge) are excluded while microorganisms are removed completely or in part. The processes to achieve this include.
• washing of raw materials and semi-finished products
• centrifugal separation of sludge components from juices
• sludge removal from juices by filtering

3.1.3 **Complete removal of microbes from foods**

The following methods are in use at present:

• microbiological filtering of juices and wines
• bactofugation, i.e. removal of microbes from liquids by centrifuging

These two methods are reported to remove almost all microbes from the liquid thus treated. Thus processes are also referred to as “mechanical sterilisation”.

3.2 **Direct inactivation of microbes-killing of microbes; sterilisation of foods**

Sterilisation of the microbe habitat is a direct inactivation or killing of all microbes present in the food. However, theoretically total sterilisation does not usually take place in preservation practices, and the so-called commercial sterilisation in considered, i.e. permanent inactivation or killing of only those microbial forms that might grow in conditions given by the composition or storage of a particular food. Abiosis is always the principle of this preservative treatment. However, since the resistance of microorganisms of the environment does not change as a result of sterilisation, the effects of sterilisation persist only up to the time when new microbes invade the food. Both physical and chemical means are used in practice:

3.2.1 **Physical methods**

• The physical means include high-temperature sterilisation by
  ➢ normal heating
  ➢ supplying mains electric current, giving resistance heating to the food,
  ➢ high-frequency heating

3.2.2 **Chemical sterilisation**

The only chemical sterilisation treatment considered are those that directly and permanently inactivate the microbes causing decomposition within the normal storage period (or else see Section 3.2); thus:

• sterilisation with oxygen (ozone, hydrogen, peroxide, etc.)
• sterilisation using oligodynamically acting silver
• sterilisation with chemicals (diethyl pyrocarbonate, DPC)
• sterilization with fumigants
3.3 Indirect inactivation of microbes

This technique comprises modification of microbe habitats so that the microbes cannot propagate and perform their enzymatic functions; anabiosis is the exclusive method in this case. None of the preservation techniques in this category is designed to completely kill all viable microbial forms, although microbes are killed by various anabiotic treatments. The methods in this group can be classified as follows, depending on the manner in which they act on the microbes:

3.3.1 Preservation through physical or physico-chemical modification of foods

- Removal of moisture from, or dehydration of, foods

These processes include xeroanabiosis or osmoanabiosis; the treatment may be both direct and indirect:

- simple drying
- concentration using an evaporator
- freezing out of water in the form of ice crystals or removal of water by membrane-based processes
- sweetening
- salting with edible salt

- Reducing the temperature below the level which does not support appreciable growth of microbes; there are two ways of doing this:
  
  - extending the shelf life of foods by chilling them to a level above the freezing point (psychroanabiosis)
  - actual freezing deep below 0°C (cryoanabiosis)

- Removal of oxygen and storage in modified atmosphere

The methods listed in this category are efficient only when combined with another natural or artificial factor which checks anaerobe activity. These methods include:

- mechanical removal of air from food environments using a vacuum pump
- treatment with carbon dioxide
- impregnation with oil
- storage in modified atmosphere

3.3.2 Chemical preservation (chemoanabiosis)

The treatments falling into this category are currently classified mainly by the origin and the degree of efficiency of the agents used; the classification may be further corrected or amended.
Chemical preservation in a narrower sense of the word, in which rather small additions of artificial chemicals are made; such chemicals would be absolutely indigestible in greater quantities, but are harmless to human health when applied in concentrations just sufficient to produce the preservative effect. Even low concentrations of these chemicals are lethal to microbes or inhibit their growth. These treatments include:

- preservation with refined chemicals
- smoking, in which the antiseptic components of the smoke act as major chemicals factors

3.2.2 Preservation by artificial alcohol treatment and artificial acidification

These methods make use of the antimicrobial effects of substances, normally natural constituents of foods present in considerable concentrations, and include:

- ethanol
- common organic acids, except those falling under 3.2.1

3.2.3 Preservation using antibiotics

3.2.4 Preservation using phytoncides

Relatively high doses of most chemical agents are lethal to microbes, so that it is rather difficult in practice to distinguish between chemoanbiosis (or narcoanabiosis) and chemical sterilisation. Organic acids, ethanol and antibiotics are also agents acting on the principle of cenoanabiosis.

3.2.5 Preservation by biological modification of foods (cenoanabiosis)

Chemical agents are formed biologically in this case in the suitably modified environment. Currently, the products formed are always the products of activities of native or inoculated microbes, i.e.

- Preservation using fermented saccharides, viz.
  - preservation by alcoholic fermentation
  - preservation by lactic acid fermentation
- Changes in which proteolysis plays a major role.

Individual preservation methods are often combined, deliberately or unintentionally, so that the treatment cannot be accurately defined. For instance, in the manufacture of compotes, the commercial sterilisation is carried out by physical means while organic acids in the fruit contribute to the preservation process; when plum butter is made, the main factor is the anabiotic removal of moisture, while the relatively increasing acidity and the boiling treatment also play a part in preservation.
4.0 REFERENCES

1.0 INTRODUCTION

Shelf life is an important feature of all foods and it is a matter of concern to all including food manufacture, wholesalers, retailers and the consumers. The shelf life of the food may be defined as the time between production and packaging of the product and the point at which it becomes unacceptable under defined environmental conditions.

Prior to determining the shelf life of food, it is essential to determine which factors limit the shelf life of food. The factors which affect the shelf life of food can be divided according to whether they are causes or effects. The latter may be determined by the laboratory tests when the shelf life is evaluated and can be grouped in four sub-categories:

1.1 Physical

Changes in colour, size & shape, texture and structure of foods.

1.2 Chemical

Lipid oxidation, Lipid hydrolysis, acidity, maillard reaction, loss of water, nutrients etc.

1.3 Microbial

Change in total viable count, coliform, yeast and mold count, growth of pathogens such as Salmonella spp., E.coli, Staphylococcus areus, Clostridium botulinum etc.

1.4 Sensory

Changes in flavour, texture and appearance.

However, a more useful approach in evaluating the factors it to consider the causes, which can further be grouped into intrinsic and extrinsic factors (Lewis and Dale, 1994; Ebrune and Prentice, 1994).

2.0 INTRINSIC FACTORS
2.1 Raw Materials

The importance of quality and consistency of the raw materials used in maintenance of shelf life of foods can not be over emphasised. The variation in source and supply of raw materials will result in a variation of factors, which influence shelf life. The quality of the raw materials is crucial if the assigned shelf life is to be met the first time and every time. Generally, all raw materials should be handled according to good manufacturing practice and if necessary any sensitive ingredients should be decontaminated before use.

2.2 Composition and formulation

This is perhaps the most important factor that influences the shelf life of foods. This is because the exact composition and formulation of a product will have profound influence on possible changes that may occur during the storage of the product. These changes can be microbiological physical and chemical/biochemical in nature, which are intimately linked to the shelf life of the product. The water content, fat content the type and state of fat, pH, Eh, salt and sugar content, etc. of food profoundly influence both biochemical and microbial changes in food.

The presence of preservative (either naturally present or added), and the synergistic effect of organic acids, pH, salt and sugar on the microbial stability also play decisive role in shelf life of foods.

2.3 Initial microflora

The type and number of initial microflora associated with raw material before food formulation has a great influence on shelf life of the product.

3.0 EXTRINSIC FACTORS

3.1 Processing

Thermal processing of foods at various time-temperature combinations, lowering of pH by fermentation or by the addition of organic acids, lowering water activity by dehydration, addition and salt or sugar, etc. are various processing techniques aimed at improving the microbiological stability of foods. An understanding of the synergistic and antagonistic reactions that take place with different processing methods when a variety of functional ingredients are used as necessary as this may have important influence on the stability of the final product.

3.2 Plant hygiene

It is necessary to ensure that plant and machines are capable of being cleaned to a satisfactory standard and if there are potential problems they must be identified and resolved as early as possible. Regular environmental monitoring (e.g. using air sampling, swabbing of machine parts and surfaces and so on) during factory trials can provide early warning of such problems.

3.3 Packaging
Packaging both in design and material terms, can have major influence on the shelf life of the product. Packaging fulfils a number of functions including protection of product from physical damage and from changes in the environment, and therefore, packaging can influence the shelf life of product in number of ways. The choice of the packaging material is important factor as it will influence the water vapour-transmission rate, oxygen transmission rate, temperature of heat processing, etc. thereby influencing the microbiological, biochemical and sensory changes in the product during storage.

3.4 Storage and distribution

All food, including dairy products, may spoil during storage and distribution due to (1) growth of microorganism (2) biochemical and chemical changes such as oxidation, rancidity, moisture migration, etc. (3) attack by vermin, birds or other pests. The microbiological or chemical changes are greatly reduced by lower storage temperature. Effective temperature control during storage and distribution is, therefore, a critical factor in preventing the development of spoilage organisms and ensuring that dairy products achieve their potential shelf-life, as well as minimising any food poisoning risk. The other major factor that can influence shelf life during the storage and distribution operation is light. This is most likely to be a critical factor in the display cabinet.

3.5 Consumer storage

The shelf life of a product mainly depends upon maintaining the integrity of "cold chain". Therefore, full account must be given for the potential abuse of the product by the retailer and consumer.

4.0 EVALUATION OF SHELF-LIFE

A common practice employed to evaluate the shelf life of a given food product is to determine changes in selected quality characteristics over a period of time. Empirical techniques such as sensory evaluation and analytical techniques such as microbiological analysis or determination of chemical parameters may be used to quantify the quality attributes of food. The shelf life failure is often identified by just Noticeable Difference (JND) i.e. "the earliest time when a difference between the quality of test and control samples can be detected by trained sensory panel's (Van Arsdel et al., 1969).

As higher storage temperature lead to increased quality deterioration, attempts have been made in the past to use mathematical models to describe changes in food quality as influenced by storage temperature. Use of chemical kinetics to model changes in food quality and Arrhenius relationship to describe the influence of temperature on the reaction rate constant has been suggested by many workers (Kwolek and Bookwalter, 1971; Saguy and Karel, 1980; Lai and Heldman, 1982). A computer aided method to simulate changes in food quality during storage of frozen foods was used by Singh (1976).

5.0 REACTION KINETICS
Chemical kinetics involves the study of the rates and mechanisms by which one chemical species converts to another. The rates of reactions are determined by monitoring the concentration of either the reactants or the products of the reactions. To analyse general quality changes in foods, the following approach is commonly used (Singh, 1994).

A general rate expression for quality attribute and may be written as follows

\[ \pm \frac{dQ}{dt} = kQ^n \]  

(1)

Where \( \pm \) refers to either decreasing or increasing value of the attribute \( Q \), \( k \) is the rate constant, \( n \) is the observed order and reaction. It is assumed that the environmental factors such as temperature humidity and light and concentrations of other components are kept constant.

### 5.1 Zero order reaction

Consider a quality attribute \( Q \) decreases linearly during the storage period, implying that the rate of loss of a quality attribute is constant throughout the storage period and it does not depend on the concentration of \( Q \). This linear relationship between quality attribute and storage time represents a zero order reaction, therefore substituting \( n = 0 \) in equation (1) we get.

\[ -\frac{dQ}{dt} = k \]  

(2)

Equation (2) may be integrated to obtain

\[ Q = Q_0 - kt \]  

(3)

Where \( Q_0 \) represents some initial value of a quality attribute and \( Q \) is the amount that attribute left after time \( t \).

At the end of shelf life, \( t_s \) is noted by the quality attribute reacting a certain level, say \( Q_e \), then

\[ Q_e = Q_0 - k t_s \]  

(4)

Therefore, the shelf-life, \( t_s \), may be calculated as

\[ t_s = \frac{Q_0 - Q_e}{k} \]  

(5)

The use of zero order rate equation (2) is useful in describing such reactions as enzymatic degradation, non-enzymatic browning and lipid oxidation, etc.

### 5.2 First order reaction
Consider a quality attribute Q that decreases in an exponential manner with storage time. The rate of loss of a quality attribute is dependent on the amount of quality attribute remaining; this implies that as time proceeds and the quality attribute decreases so does the rate of reaction. This exponential relationship between quality attribute and time represents a first order reaction n = 1, and equation (1) is modified as follows:

$$- \frac{dQ}{dt} = kQ$$

(6)

by integration, we get

$$\ln \frac{Q}{Q_0} = -kt$$

(7)

Where Q is the amount of quality attribute left at time 't'.

At the end of shelf life, t_s for a certain final level of quality attribute Q_e, we can also write equation (7) as:

$$\ln \frac{Q_e}{Q_0} = -kt_s$$

(8)

or

$$t_s = \frac{\ln \frac{Q_e}{Q_0}}{k}$$

(9)

The types of food deterioration reactions that show first order losses include vitamin and protein losses and microbial growth.

Most reactions showing losses in food quality may be described by zero or first order, however, there are some studies in the literature that indicate use of other orders (Singh and Heldman, 1976; Jayraj Rao, 1993).

6.0 TEMPERATURE EFFECTS

The influence of temperature on the reaction rate may be described by using the Arrhenius relationship, as follows:

$$k = k_o \exp \left[ - \frac{E_a}{RT} \right]$$

(10)
Where $k_o$ is the pre-exponential factor, $E_a$ is the activation energy, $R$ is the ideal gas constant and $T$ is the absolute temperature.

Another parameter that is often used in the literature to describe the relationship between temperature and reaction rate constant is the $Q_{10}$

Value $Q_{10}$ is defined as follows:

$$Q_{10} = \frac{\text{reaction rate at temperature (T+10)°C}}{\text{reaction rate at temperature T°C}} \quad (11)$$

7.0 DEVELOPMENT OF COMPREHENSIVE SHELF LIFE PREDICTION MODEL

Shelf life of food product is the period of storage during which the organoleptic quality remains suitable for consumption. The sensory properties of the product during storage are in turn, governed by progression of a host of deteriorative reactions. These reactions may induce changes of chemical, biochemical and physical nature. The multiplicity and extent of these changes determine the period up to which the product may remain acceptable to consumers. The rate of these changes are, in turn, influenced by the temperature of storage. For prediction of shelf life of any food product, therefore, information relating to the physico-chemical parameters affecting sensory quality as well as dependence on storage temperature and time must be known and integrated into a model. Such comprehensive models have been reported by Jayraj Rao (1993) and Ananthanarayanan et al., (1993).

Most of the changes occurring in the product can be measured by objective tests and interpreted in quantifiable terms. Relationships between these changes and sensory score helps in objective measurement of human sensory perception. Different models such as linear, exponential and power as given below, may be employed to establish the relationship between sensory score and chemical parameters.

**Linear** : $S = a + b \times X \quad (12)$

**Exponential** : $S = a e^{bX} \quad (13)$

**Power** : $S = aX^b \quad (14)$

Where, $S$ is sensory score  
$X$ is chemical parameter  
a and $b$ are coefficients

Sometimes, the sensory score is dependent on more than one chemical parameter, such as

$$S = a_1 + b_1 X_1 + b_2 X_2 \quad (15)$$

Where $X_1$ and $X_2$ are chemical parameters.
The rate of change of chemical parameter (s) during storage can be obtained from equation (1) for reaction kinetics and dependence and reaction rate constants (k) with temperature can be worked out using Arrhenius equation (10). The equation relating sensory data with chemical parameter, equation describing rate of change of chemical parameter, and equation relating reaction rate with storage temperature can be combined to yield a model which could predict the sensory quality of product at a given storage time and temperature condition. Assuming the chemical parameter follows a zero order reaction kinetics and sensory and chemical parameters are related linearly, the model can be written as:

\[ S = a + b \left[ X_0 \cdot (k_0 e^{-\frac{E_a}{RT}})^t \right] \quad \text{OR} \]

\[ t = \frac{(s - a)}{b} - \frac{X_0}{k_0 \exp\left(-\frac{E_a}{RT}\right)} \]

Where,

- \( S \) = Sensory Score after storage time
- \( t \) = Storage period
- \( X_0 \) = Chemical parameter at \( t = 0 \)
- \( K_0 \) = Arrhenius constant
- \( E_a \) = Activation energy
- \( R \) = Universal gas constant
- \( T \) = Absolute storage temperature
- \( a \) and \( b \) = Coefficients,

## 8.0 REFERENCES


1.0 INTRODUCTION

India has emerged as the largest milk producer country in the world with a turn over of 74 MT. The dairy industry is an important segment of food industry in India. Producing large quantity of milk is not enough. Milk and milk products should be of very good quality. These should be free from harmful additives, pesticide residues, antibiotics, microbes and remain so for a period it is intended to be consumed. The quality of the products must conform to international standards to be globally competitive. The trade reforms initiated by WTO in 1994 on Uruguay Round Agreement on Agriculture have changed the business environment. The activities in Dairy Industries and Government have increased tremendously so as to ensure conformation of quality of the products to international norms for facilitating international trade. The methods employed for food safety programmes within the dairy industry vary considerably depending upon the types of process and size and nature of the sources available.

To achieve excellence in dairy products, safety has assumed great significance with the advent of HACCP standards in 1997 by CAC. The codex standards have been recognised internationally as bench mark for measuring food safety which can be ensured through HACCP system and good manufacturing practices.

1.1 Quality

Quality embraces many characteristics such as chemical, microbiological, nutritional, physical, aesthetic and is difficult to define exactly. In dairy industry, quality of the products is tradionally ensured by employing inspection and test methods under the banner of ‘quality-control and Quality Assurance’. In the newer context, concept has moved from: Inspection to Quality Control to Quality Assurance to continuous improvement and finally to Total Quality Management (TQM).

1.2 Quality control

Quality control refers to the adjustment of attributes within the prescribed standards and is defined as the operational techniques and activities that are used to fulfil requirement for quality. It revolves around the assessment of specific product and process attributes to confirm standards & specifications have been met.
1.3 Quality assurance

Quality assurance is focussed on the entire process of food handling involving raw material, product manufacturing, packaging, testing storage, transportation, distribution and customer service. The major emphasis of a quality assurance system is on process control so as to ensure that:

- products are made consistently to specifications
- manufactured products are protected & preserved
- non-conforming products and associated quality costs are avoided

With the adoption of the World Trade Organizations Agreement on the “Application of Sanitary and Phytosanitary Measures (The SPS Agreement) and Agreement on Technical Barriers to Trade (The TBT Agreement), a new emphasis is placed on Codex Food Standards. Codex code of Hygienic practices are based on good manufacturing practices and HACCP Principles and Risk Analysis.

2.0 GOOD MANUFACTURING PRACTICES (GMP)

GMP standards define requirements for the management and control of activities and operations involved in the manufacturing, storage and distribution of foods. Elements of activities and operation are identified as determinants of product quality and food safety and standards are established for each element. The year of experience in the plant results in the development of GMP to be followed. These practices should aim to maximise productivity and minimize exposure to hazards. The productivity depends upon many factors such as planning, requirement of ingredients and their quality, manufacturing techniques to be followed and their process control, packaging, storage, distribution, optimum use of skilled man power and quality assessment.

3.0 HAZARD ANALYSIS CRITICAL CONTROL POINT (HACCP)

HACCP is a logical method for assessing the hazards and risks associated with the manufacturing of food products. It enables the identification of critical control points (CCPs) in the manufacturing process and application of monitoring, control and verification requirement HACCP eliminates the need for finished product testing. It is totally focussed on food safety. There are seven principles of HACCP.

1. Identify the potential hazards associated with food production and the preventive measure for their control
2. Determine the procedures to eliminate these hazards
3. Establish critical limits within which CCP may be under control
4. Establish a system to monitor control of CCP’s
5. Establish a corrective action to be taken when a particular CCP is not under control
6. Establish procedures for testing whether HACCP is working satisfactory
7. Document all procedures & record
Application of HACCP is compatible with implementation of ISO-9000 Quality Management System. Both these systems ensure safe and wholesome food to the consumer. Their application lays more emphasis to prevention of hazards at all stages from production to final consumption than finished product inspection and testing. ISO-9000 series of standards are used as framework for establishing Quality Management System. These ensure quality framework to guarantee consisting of operation. Whereas T.Q.M. focussed on continuous improvement.

After several meetings held in 1978 by the technical committees quality-control systems and management standards called ISO-9000 were evolved. These were issued as world standards in 1987. ISO-9000 standards are applicable to all types of industries engaged in manufacturing construction and servicing irrespective of their geographical location.

- ISO-9000 series consists of 4 models:
  - ISO-9001: It is meant for industries involved in design, development, production installation & servicing
  - ISO-9002: It is a quality system applicable only for industries engaged in production
  - ISO: 9003: It is used by those industries which are engaged in assuring conformance to specification at final inspection and test
  - ISO:9004: It serves as a guideline for developing quality management system, quality cost and product sanity and liability.

The equivalent Indian standards are IS: 14000 issued by BIS having the corresponding models as IS: 14001, IS: 14002, IS: 14003 and IS: 14004, ISO-9000 is like a visa for our goods for entering European market of 12 nations.

4.0 TOTAL QUALITY MANAGEMENT

TQM is the tertiary stage of quality improvement for food industries, following the consolidation of Q. A. programme and implementation of a QMS. The main focus of TQM is to improve

- The material and services supplied to the organization or consumer
- All the processes within an organization
- Degree to which needs of customers are met now and in the future

Some of the pre-requisites for the successful implementation of TQM are:

- A strategic quality plan and annual quality improvement plan which cover all products, services and internal department.
- Education and training of each and every employee
- Use of quality measure and statistical methods to measure progress and process control
- Bench marking of all business processes and products which are the best and a comparison of level & growth.
The overall performance of TQM is shown in the consolidated form in the figure 1.

Total Quality Management – an integrated approach

5.6 Certification of HACCP system

There are many internationally recognised certification agencies, which certify industries/enterprises against codex standards on HACCP system. The main steps involved in a certification process are:

- Document review for its adequacy
- Preliminary visit to the organization to assess the degree of preparedness
- Final audit of the documented system in place in the organization
- Award of certification if system complies with the requirements

6.0 FUTURE STRATEGIES

The present day dairy industry will have to cope with dual pressure of intense competition requiring more efficient manufacturing programmes along with innovative developments in processing and at the same time assuring food safety. An ideal proposition for the emerging scenario would be to use HACCP along with TQM. TQM can be used to improve quality and lower down cost while HACCP can be used to assure food safety. HACCP works most efficiently in a TQM environment where food safety, quality and productivity get concerned in total system approach to manufacturing to affect a more reliable system, leading to greater productivity & profitability.

The regulatory agencies lay more emphasis on safety while business emphasize on both quality and safety. HACCP ensures that food is not only good at the point of manufacture but also through its shelf life period. It is logical to select ISO-9001 route to implement HACCP as it is well known widely practical system around the world with over 350000 companies already certified. It would be much easier to induct HACCP in an already operating ISO-9000 system.
7.0 REFERENCES


Principal for the Establishment and Application of Microbiological criteria for Food CAC/RCP-22, 1997.


1.0 INTRODUCTION

In Dairy and Food Industry, the maintenance of hygienic conditions is a pre-requisite to the production of quality products. This is accomplished by the use of appropriate cleaning agents with or without sanitizers. Thus, the word 'detergent', as it applies to the dairy industry means a substance or formulation used for cleansing or removal of soil, dirt or foreign matter from a surface. For efficient cleaning of dairy and food equipments different types of detergents are being currently employed. However, reports indicate that most of the formulations tested do not give satisfactory results in removal of milk stones and have one limitation or the other. The use of synthetic detergents also does not solve the two major problems of the dairy industry. Removal of proteinaceous milk stones in CIP cleaning and prevention of biofouling of UF and RO membranes. Moreover, these synthetic detergents have a drawback of creating environmental pollution problems, due to their non-biodegradability, corrosiveness and toxicity. Their prolonged use in larger dairy plants, on several occasions, have led to the formation of slumps, resulting in unhygienic conditions in the surroundings. Further such compounds, even in small quantities, cause considerable increase in the BOD levels thus disturbing the ecological balance of the area.

In this context, there is a need to use "BIODETERGENT OR BIOCLEANERS" which offer a better option to the synthetic detergents with respect to their biodegradability, low toxicity, non-corrosiveness environmental-friendliness, enhanced cleaning properties and their increased efficiency and stability in different formulations.

2.0 DETERGENT

Detergent is defined as a substance which when added to water increases the cleaning properties of that water. Detergents are used to remove milk residues and other materials adhering to different equipments, which would otherwise lead to further multiplication of microbes. Ideal detergents should have the following desirable properties:

- Wetting and penetrating power-must wet, penetrate and dispose soil and remove it from walls of equipments.
In dairy and food industry, various types of detergents and cleaners are used and each one has one or more limitations. These are presented in table 1:

**Table 1 Common detergents & sanitizers used in dairy & food industry**

<table>
<thead>
<tr>
<th>Detergent</th>
<th>Functions</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| 1. Alkalies:               | Digest, disrupt or dissolve soil especially protein, act as emulsifier, bactericidal agents, generally used at 0.2 - 2% (NaOH) | i) Some of these have poor solubility and wetting power  
ii) NaOH corrosive towards Al, Tin and Zn especially at higher concentration. (>2.0%) |
| a) Sodium hydroxide       |                                                                           |                                                              |
| b) Sodium carbonate       |                                                                           |                                                              |
| c) Sodium bicarbonate     |                                                                           |                                                              |
| d) Sodium silicates       |                                                                           |                                                              |
| e) Sodium phosphates      |                                                                           |                                                              |
| 2. Acids:                 | Remove hard deposits such as milk stones, such deposits do not dissolve in alkalies, generally HNO<sub>3</sub> (0.5%)  
Phosphoric acid (2.0%) used | Strong acids are corrosive to metal surface and dangerous also |
| a) Nitric Acid            |                                                                           |                                                              |
| b) Sulphuric Acid         |                                                                           |                                                              |
| c) Hydrochloric Acid      |                                                                           |                                                              |
| d) Phosphoric Acid        |                                                                           |                                                              |
| e) Acetic Acid            |                                                                           |                                                              |
| 3. Complex Phosphates:    | Water softening, soil displacement by emulsification, peptization prevention of redeposition of soil | Excellent but unstable in hot solution and in presence of strong alkalies. |
| a) Tetra sod. pyrophosphate |                                                                       |                                                              |
| b) Sod. tripolyphosphate  |                                                                       |                                                              |
| c) Sod. tetraphosphate    |                                                                       |                                                              |
| d) Sod. hexametaphosphate |                                                                       |                                                              |
| 4. Chelating Agents:      | Sequestering, water softening, removal of mineral deposition.            | --                                                          |
| EDTA (Ethylene diamine tetra acetic acid) |                                                                |                                                              |
| 5. Wetting Agents:        | -- Wetting and penetrating properties in soil  
-- Stable dispersion  
-- Emulsion formation | QAC are expensive. |
| a) Anionic (sod. salt of various complex organic materials |                                        |                                                              |
| b) Non ionic e.g. teepol  |                                                                           |                                                              |

Considering the above limitations and owing to the fact that these synthetic detergents are non-biodegradable, corrosive & toxic and their prolonged use leads
the formation of slumps, creating unhygienic conditions in the surroundings and increase BOD levels thus disturbing ecological balance of area.

Latest technology includes “BIODETERGENTS AND BIOCLEANERS”. Detergent formulation containing either micro-organisms or their metabolites especially enzymes or products of biological origin. Of these, enzyme detergents are proving extremely useful because:

- Keep check on environmental pollution
- Biodegradable
- Low toxicity
- Non-corrosiveness
- Environmental friendliness
- Enhanced cleaning properties

3.0 ENZYME BASED DETERGENT FORMULATIONS

Presently, Proteases, amylases, lipases and cellulases make up the major portion of the market for industrial enzymes in cleaning applications. Proteases, the first enzymes to be introduced into detergent formulation, are used to clean difficult to remove protein based residues like blood, egg & milk (casein and whey proteins). Amylase have been included in detergent formulations to remove starch based stains such as gravy, pudding and potato. Lipases demonstrate their cleaning advantages and triglyceride based residues such as margarine, milk fat and oil. Most recently, cellulases have been included for colour maintenance or restoration benefits on cotton fabrics. All of these enzymes are specific for a particular application, yet all are classified as hydrolyzing enzymes or hydrolases based on their mechanism of action (Table 2).

Table 2 Hydrolase enzymes and their substrate

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Enzyme classification</th>
<th>Substrate</th>
<th>Natural Source</th>
<th>Reaction Catalyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Protease</td>
<td>Proteins polypeptides</td>
<td>Proteinaceous food, milk, meat products and cheese</td>
<td>Hydrolysis of amide or peptide bond</td>
</tr>
<tr>
<td>2.</td>
<td>Lipase</td>
<td>Tri, di, mono glycerides</td>
<td>Milk fat, natural animal &amp; plant fat Margarine, oils</td>
<td>Ester bond hydrolysis</td>
</tr>
<tr>
<td>3.</td>
<td>Amylase</td>
<td>Amylose Amylopectin</td>
<td>Starch based soils flour, potato and gravy</td>
<td>Hydrolysis of 1, 4 glycosidic bond</td>
</tr>
<tr>
<td>4.</td>
<td>Cellulase</td>
<td>Cellulose</td>
<td>Amorphous cellulose vegetable, fruit and grains or cereals</td>
<td>Hydrolysis of β 1, 4 glycosidic bonds.</td>
</tr>
</tbody>
</table>

4.0 HISTORICAL DEVELOPMENT OF BIODETERGENTS
The original idea of using enzymes was first described by Dr. Otto Rohm. He patented the use of pancreatic enzymes in presoak detergent composition, to improve their ability to remove proteinaceous stains and first enzymatic detergent, named “BURNUS” was launched. But it was not commercialized because enzyme could be made available by extraction of pancreatic glands in only limited amounts.

Moreover, functional enzymes Trypsin and Chymotrypsin with pH optimum detergent between 7-9 were sold only until 1940s. The first detergent containing a bacterial protease BIO 40, produced by Schnyder in Switzerland appeared on market in 1959, quickly followed by very successful in Netherlands. The enzymes used were Alkaline Serine Protease from Bacillus licheniformis. Consequently, since 1971 application of amylases, lipases and cellulases also came to picture in detergent formulations.

5.0 PROTEASES

Protease enzymes were first hydrolases introduced into detergent formulations specifically for the degradation of protein-based stains. A primary function of these enzymes is digestion of proteins to their constituent amino acids. Proteases catalyze the hydrolysis of proteins by breaking the peptide bond that links the amino acids into a polypeptide chain. Proteases have been classified according to the nucleophile or reactive component found at their catalytic sites. There are now four broad categories of proteases: Serine, Sulphydryl, Metallo and Aspartyl proteinases. Of all these classes of proteases, only the serine proteases are suited for inclusion in detergent formulations. The aspartyl proteinases will function poorly or not at all in alkaline pH range of detergent formulation. The Metallo proteases will not survive the builders present to reduce water hardness, and the sulphydryl enzymes are generally too slow and are not compatible with oxidants such as bleach.

The first enzymatic detergent contained enzymes from pig pancreatic glands. But was not very effective in cleaning purposes because it was not stable in high alkalinity of detergent formulation. Therefore, a large number of microorganisms were screened such as yeasts, fungi and bacteria & among bacteria, bacilli are superior to other genera for large scale enzyme production in large fermentation vessels of certain technological advantages.

5.1 Advantages of microbial proteases

i) Cultivation time of microbial proteases is short as compared to other microorganisms, which reduces costs by keeping aeration time and agitation time brief.

ii) Desired proteases are secreted into fermentation broth and usually proteases are pure other enzymes are secreted in only small amounts (or are digested by protease: autopurification).

iii) Cell mass can be easily removed by basic operations such as centrifugation or filtration, with filter presses or belt filters.

iv) Bacillus species produced proteases with sufficient stability in alkalinity of detergent formulation.
v) Enzymes are not inactivated by surfactants, oxidative (bleaching) agents and elevated temperatures (upto 90°C) normally higher temp. employed during CIP in dairy and food industry.

Several species of bacilli are used for production of enzymes. The first species to be used was *Bacillus subtilis* for production of alkaline proteases in large amounts. However, strain has some disadvantages: produced three enzymes: amylase, neutral protease and alkaline protease & purification is difficult. Another drawback of *B. subtilis* was its filterability and biomass removal was difficult. Later on, other bacterial sp. such as *B. licheniformis* and other alkalophilic strains were used for protease production (Table 3).

**Table 3 Commercially available proteases containing detergents**

<table>
<thead>
<tr>
<th>Brand</th>
<th>Producer</th>
<th>Genetic modified property</th>
<th>Microbial spp</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILEZYME</td>
<td>Miles</td>
<td>-</td>
<td><em>Bacillus subtilis</em></td>
</tr>
<tr>
<td>ALCALASE</td>
<td>Novo Nordisk</td>
<td>-</td>
<td><em>B. licheniformis</em></td>
</tr>
<tr>
<td>MAXATASE</td>
<td>Gist-Brocades</td>
<td>-</td>
<td>---do--</td>
</tr>
<tr>
<td>OPTIMASE</td>
<td>Solvay Enzymes</td>
<td>-</td>
<td>---do--</td>
</tr>
<tr>
<td>SAVINASE</td>
<td>Novo Nordisk</td>
<td>-</td>
<td><em>B. lentus</em></td>
</tr>
<tr>
<td>MAXACAL</td>
<td>Gist-Brocades</td>
<td>-</td>
<td><em>B. alcalophilus</em></td>
</tr>
<tr>
<td>OPTICLEAN</td>
<td>Solvay Enzymes</td>
<td>-</td>
<td><em>B. alcalophilus</em></td>
</tr>
<tr>
<td>KAZUSASE</td>
<td>Showa Denko</td>
<td>-</td>
<td>Alkalophilic species</td>
</tr>
<tr>
<td>PURAFECT</td>
<td>Genencor</td>
<td>-</td>
<td>Alkalophilic species</td>
</tr>
<tr>
<td>ESPERASE</td>
<td>Novo</td>
<td>-</td>
<td><em>Bacillus species</em></td>
</tr>
<tr>
<td>BLAP</td>
<td>Henkel</td>
<td>-</td>
<td><em>Bacillus species</em></td>
</tr>
<tr>
<td>MAXAPEM</td>
<td>Gist-Brocades</td>
<td>Genetically modified enzyme enhanced oxidation stability</td>
<td><em>B. alcalophilus</em></td>
</tr>
<tr>
<td>DURAZYM</td>
<td>Novo Nordisk</td>
<td>-do-</td>
<td>Alkalophilic species</td>
</tr>
</tbody>
</table>

### 6.0 LIPASES

Different greasy food stains (tomato based sauces, butter, dressings, edible oils and chocolate), cosmetic stains animal and vegetable fat including milk fat components of milk stones deposited on equipments of dairy and food industry are not removed only by application of proteases in detergent formulations.

The introduction of lipase in detergent formulations is of more recent than introduction of protease & amylase. Novo Nordisk launched the first lipase product in 1987. Lipase from Humicola lanuginose – Trade name LIPOLASE was incorporated by Lion in their HI Top brand on the Japanese market. Subsequently, Genencor Inc. followed in 1993 with LUMAFAST (a cutinase from *Pseudomonas meddocina*) and Gist-Brocades in 1995 with LIPOMAX (lipase from *Pseudomonas alcaligenes*)
6.1 Mode of action

Lipases are glycerol ester hydrolases capable of hydrolyzing the water-insoluble triglyceride components into more water soluble products such as mono and diglycerides, free fatty acids and glycerol. Fatty acid moiety of triacyl glycerol can range from short-chain to long chain C18 = stearic acid) or may be saturated or unsaturated fatty acid. Only those with shorter chain lengths are slightly soluble. Lipases show substrate specificity. It's activity is neglected towards monomeric, water soluble form and is largely increased when substrate is in aggregated (emulsified insoluble form. Because lipase is apparently active only at water-substrate interface, this phenomenon is referred to as interfacial activation. Mechanism of action of lipase involves:

- Physical binding of enzyme to the surface (at lipid-water interface), a confirmation change takes place making the active site accessible to substrate molecule.
- Enzyme form a complex with substrate molecule which results in carboxyl ester bond hydrolysis.

6.2 Limitation of lipases as detergent

As lipases can hydrolyze fat and have improved the cleaning, however lipase use as a part of a detergent present some difficulties:

- Lipase similar to proteins can be adversely affected by extremes in temperature, pH ionic strength and matrix composition.
- Temperature effects are extremely pronounced in lipase ability to hydrolyze fatty oils in situ. It’s activity higher at elevated temperature but remarkable reduced at low temperatures (20°C/10 min., granular detergent + lipolase) as target sites are solids, reducing accessibility to lipase.
- It shows complete removal after several wash cycles and is considered a major drawback.

It shows sensitivity towards inhibition by various detergent ingredients e.g.

- Surfactants non ionics and particularly anions generally cause irreversible unfolding, denaturation and inactivation of enzymes.
- Bleaching agents capable of oxidizing amino acids such as cysteine, methionine and aromatic ones such as tryptophan, phenylalanine and tyrosine. The oxidized enzyme can be considered to be cropped with a reduced catalytic efficiency.
- Binders- because of their ability to bind divalent cations such as Ca^{2+} results in unfolding and irreversible inactivation of enzymes.

Finally, the presence of protease in a detergent may cause proteolysis of other enzymes present.

6.3 Genetically modified lipases
To counteract the above limitation, the properties of lipase are improved by genetic engineering.

*Pseudomonas alcaligenes* lipase was improved by inducing mutation at active site i.e. replacement of methionine at position 21 by leucine influenced the cleaning performance. On inducing mutation, it was found that mutant M21L would become active ingredient of new product LIPOMAX instead of wild type enzyme. The gene from lipase of *Humicola lanuginosa* has been cloned into fungus *Aspergillus oryzae* because of good fermentation properties of this genus. The activity of enzyme is improved in terms of

- increase of wash performance
- increased cleaning in first wash cycle
- increased efficiency preferentially at lower temperature
- broadening of stain specificity
- lowering sensitivity towards inhibition by appropriate mutation (deletion or substitution) or transfer of gene from one organism to another.

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Origin of organism</th>
<th>Genetically modified</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LIPOLASE</td>
<td>Humicola lanuginosa</td>
<td>Gene cloned in Asp. Oryza</td>
<td>NOVA NORDISK; USA</td>
</tr>
<tr>
<td>2. LUMAFAST</td>
<td>Pseudomonas glumal</td>
<td>Gene cloned in Bacillus lentus</td>
<td>GENENCOR: California</td>
</tr>
<tr>
<td>3. LIPOMAX</td>
<td>Pseudomonas alcaligenes</td>
<td>Self Cloning</td>
<td>GIST-BROCADES; The Netherlands</td>
</tr>
</tbody>
</table>

### 7.0 STARCH

Starch is a major component of most of our daily food all over the world. Consequently, it is found on clothes or dishes in most stains generated during preparation or consumption of meals containing food ingredients such as sauce, porridge, mashed potatoes or chocolate. This creates a need for effective removal of starch from clothes, dishes by detergent composition especially in automatic dishwashing. Phosphorylated starches are used as emulsifiers for preparation of salad dressings, ice-cream, mustard, gravy, and similar food products. Therefore, residues removal is essential in food and dairy industry equipments after their manufacture as well as from textiles & clothes after its consumption by consumer.

The starch degrading enzymes are α-amylase, isoamylase, pullulanase, glucoamylase, etc.α-amylases are mainly used in detergents although recently pullulanases or isoamylases are also described from *B. subtilis*, *B. amyloliquefaciens* and *B. licheniformis* and are available under different trade names (Table 5).

<table>
<thead>
<tr>
<th>Brand name</th>
<th>Origin of organism</th>
<th>Genetically modified</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0 STARCH</td>
<td>Starch is a major component of most of our daily food all over the world. Consequently, it is found on clothes or dishes in most stains generated during preparation or consumption of meals containing food ingredients such as sauce, porridge, mashed potatoes or chocolate. This creates a need for effective removal of starch from clothes, dishes by detergent composition especially in automatic dishwashing. Phosphorylated starches are used as emulsifiers for preparation of salad dressings, ice-cream, mustard, gravy, and similar food products. Therefore, residues removal is essential in food and dairy industry equipments after their manufacture as well as from textiles &amp; clothes after its consumption by consumer. The starch degrading enzymes are α-amylase, isoamylase, pullulanase, glucoamylase, etc.α-amylases are mainly used in detergents although recently pullulanases or isoamylases are also described from <em>B. subtilis</em>, <em>B. amyloliquefaciens</em> and <em>B. licheniformis</em> and are available under different trade names (Table 5).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The activity of bacterial alpha amylase strongly depends on the pH, temperature and the presence of calcium as a stabilizer. A certain level of Ca\(^{2+}\) ion is required to maintain the activity of alpha amylase. Ca\(^{2+}\) stabilizes the enzyme against denaturation and the attach of proteases. The optimum activity lies in pH range 5-8 (Table 6).

**Table 6 Optimum activity of amylases**

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Source organism</th>
<th>pH range</th>
<th>Optimum pH</th>
<th>Temp. range (°C) (inactivation temp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bacterial α-amylase</td>
<td>B. subtilis, B. Amyloliquefaciens</td>
<td>4.5 – 9.0</td>
<td>6.5 – 7.5</td>
<td>70-85 (95°C)</td>
</tr>
<tr>
<td>2. Thermostable α-amylase</td>
<td>B. Licheniformis</td>
<td>5.8 – 8.0</td>
<td>7.0</td>
<td>90-105 (120°C)</td>
</tr>
</tbody>
</table>

These amylases may be combined with other enzymes to improve detergent properties and to harness max. benefit or application in number of other fields especially for cleaning of dairy and food equipments.

**8.0 APPLICATIONS OF BIODETERGENTS IN MEMBRANE CLEANING**

**8.1 Membrane fouling during ultrafiltration**

The application of UF and RO membrane systems in the dairy, food, pharmaceutical & chemical industries is becoming indispensable. However, in dairy and food industries, these processes offer capability of concentrating and fractionating liquid foods like milk, whey, fruit juices and egg white, clarification and sterilization of fruit juices, wines, vinegar and beverages and whey desalting without thermal denaturation or degradation of heat-sensitive constituents like proteins or vitamins.

As active membrane surface comes in contact with stock and even a small degree of adsorption causes pore blockage resulting in clogging of filters & the phenomenon is referred as membrane fouling, thereby cause a reduction in permeate flux rate and loss in product.

**8.2 Common agents using membrane fouling**
The common agents involved in membrane fouling are mostly proteins, inorganic salts such as Ca+ ion and fat residues. Whey proteins are smaller than casein micelles thus constitute main fouling agents. $\alpha$-lactalbumin has strongest gel forming tendency than BSA and existed as granules while $\beta$-lg ($\beta$-lactalbumin) is found to be major foulant as capable of forming strands or sheets. These whey proteins $\alpha$-la & $\beta$-lg formed 95% of proteinaceous membrane deposits during UF of whole milk. During whey concentration, Ca also forms one of primary foulant as it exists in two forms, a permeable and impermeable fraction. The latter exist as colloidal phosphate and attached to $\beta$-lg. When conc. of calcium phosphate in whey retentate exceeded its solubility index, it tended to crystallize forming deposits as specific membrane foulant, thereby reducing the flux.

8.3 Control of membrane fouling

8.3.1 Pretreatment

Many pretreatments are often given to eliminate or reduce the chances of fouling of membranes. These are:

- Clarification
- Filtration
- Microfiltration
- Pre-heat treatment
- Alteration of pH
- Decalcification or chelation of calcium

In spite of all the precautions taken to prevent fouling, it can not be totally avoided, therefore recently it has been reported that application of BIODETERGENTS & BIOCLEANERS especially enzyme detergents containing proteases can be used for effective cleaning of UF and RO membranes and to check the fouling of membranes so as to increase the life of these membranes as latter are very costly.

As usual cleaning in dairy and food industry involves use of strong acid and alkaline treatments with HNO$_3$ or phosphoric acid and NaOH respectively followed by flushing with water and sanitization. However, strong acids and alkalies can damage the membranes at higher temperature and pH condition & thereby shortens the life of membranes. Therefore, enzyme detergents containing proteases as described earlier such as MILEZYME, ALCALASE, MAXATASE, TERG-A-ZYME along with protease, OPTIMASE, DURAZYM and MAXAPEM are useful.

8.4 Milk-stones formation on dairy equipments

For efficient cleaning of dairy equipments, different types of detergents are being currently employed. However, these do not give satisfactory results, in removal of milk stones. Milk stones consist largely of calcium phosphate,
precipitated and denatured milk proteins and insoluble calcium salts from hard water and washing solutions. It has the following approximate composition:

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>2.7 – 8.7%</td>
</tr>
<tr>
<td>Fat</td>
<td>3.6 – 17.7%</td>
</tr>
<tr>
<td>Protein</td>
<td>4.4 – 43.8%</td>
</tr>
<tr>
<td>Ash</td>
<td>42 – 67.3%</td>
</tr>
</tbody>
</table>

Therefore efficient removal of milk stones from dairy equipments can be achieved by using BIODETERGENTS containing proteases as denatured proteins are very difficult to remove even by using strong alkali solution practiced under normal CIP cleaning.

8.5 Another major problem: biofilm formation on dairy & food contact surfaces

In nature and food systems, micro organisms get attracted to solids surface conditioned with nutrients sufficient for their viability and growth. These micro organisms initially are deposited on the surfaces and later get attached, grow and actively multiply to form a colony of cells. These masses of cells further become large enough to entrap organic and inorganic debris, nutrients and other micro organisms leading to the formation of a microbial biofilm. In dairy and food processing equipments, when any food or milk residues remains, they deposit on the surface and then micro organisms start forming biofilms and even CIP procedures can not prevent the accumulation of micro organisms on equipment.

8.5.1 Control of biofilms

Generally, an effective cleaning and sanitization programme, when included in the process from beginning, will inhibit both accumulation of particulates and bacterial cells on equipment surfaces and subsequent biofilm formation. However, removal of biofilm is very difficult and demanding task, a complete and cost-effective cleaning procedure should be developed.

8.5.2 Use of biodetergent and biocleaners in controlling biofilm

Biodetergent and biocleaners have proved effective in cleaning the extracellular polymers which form the biofilm matrix and thus helps in removal of biofilms. The specific enzymes required vary according to the type of microflora making up the biofilm.

- In one study, a blend of enzyme mixture consisting of Protease, \( \alpha \)-amylase and \( \beta \)-glucanase was found effective in cleaning a simulated industrial biofilm.

- Workers of Genencor International, Inc., USA have developed enzymes called endoglycosidases which deglycosylate biopolymers like glycoproteins which are widely distributed in living organisms. They employed r-DNA
technology to develop Endo-β-N-acetyl-glucosaminidase H (endo H) as cleaning agents. Endo H had a unique property to remove bacteria such as staphylococci and *E. coli* from contact surfaces.

- Very recently, an enzymatic preparation comprising of exopolysaccharide-degrading enzymes, particularly cationic acid-degrading enzymes, derived from a *Streptomyces* isolates was reported for the removal and prevention of biofilm formation.

By using enzyme detergents (BIODETERGENTS and BIOCLEANERS) we can prevent the biofilm formation on dairy and food industry equipments/processing lines.

### 9.0 CONCLUSION

As maintenance of hygienic conditions is a pre-requisite to the production of quality products use of synthetic detergents and cleaning agents does not solve the major problems of dairy and food industry such as removal of proteinaceous milk stones after CIP, membrane fouling in UF and biofilm formation on equipment surfaces. Latter is a more emerging problem now a days. Moreover, these synthetic detergents are non biodegradable, corrosive & toxic also. Therefore, more emphasis should be given in use of BIODETERGENT & BIOCLEANERS which are biodegradable, less toxic, non-corrosive, present environmental pollution, enhance cleaning properties, have increased efficiency and stability. Therefore, these are referred as “green chemicals” and are becoming an ideal consumer choice.

Considering the Indian scenerio, there is a need to increase production of these BIODETERGENTS & BIOCLEANERS in our country so that import can be reduced. Also, there is need of awareness among people especially in dairy and food industry so that hygienic conditions in plant can be maintained leads to production of quality products.

### 10.0 REFERENCES

1.0 INTRODUCTION

Water activity is an important control variable in food processing. It is closely related to the physical, chemical and biological properties of foods and other natural products. Specific changes in colour, aroma, flavour, texture, stability and acceptability of raw and processed food products have been associated with relatively narrow water activity ranges. Water activity has direct effects upon various chemical reactions (Labuza 1980), enzymatic reactions and the proliferation of microorganisms (Troller, 1980). An understanding of sorption phenomenon in foods provides valuable information to characterize storage and packaging problems. Isotherm parameter are needed for evaluating the thermodynamic functions of the water sorbed in foods and are essential in prediction of drying time for food stuffs and in appraising the shelf life of the food products in packaging material.

2.0 SORPTION PHENOMENA IN FOODS

In biological systems such as foods, water is believed to exist with unhindered and hindered mobility and is referred to as free water which is similar to liquid water and as bound water. Bound water is generally defined as sorbant or solute-associated water that diffuses thermodynamically from pure water. Bound water has a reduced solubility for other compounds, causes a reduction in the sorbant and exhibits a decrease in its diffusion coefficient with decreasing moisture content. The decreased diffusion velocity impedes drying process because of slower diffusion of water to the surface. Thus the types of interaction between water and food matrix, pH, temperature and other related factors exert a cumulative influence on foods in accordance with their changing values during the course of pretreatment and drying operations (Rizvi, 1983).

In has been established that the actual content of water is not a critical factor in product stability, but some other factors related to the ‘nature’, ‘state’ or availability of water determine eventual deterioration. In more general terms, the properties of a food system are influenced by the water-binding energies of specific molecular groups and interaction among hydrophilic chemical constituents. The total binding energies of constituent chemical groups are reflected in the equilibrium water vapour pressure. At constant temperature, the vapour pressure may be expressed as equilibrium relative humidity (ERH), the related analogous term water activity (ERH/100) being defined as the ratio of equilibrium vapour pressure to the vapour pressure of pure water at the same temperature.
3.0 SORPTION ISOTHERMS

An isotherm establishes the equilibrium relationship, at a particular temperature, between the amount of water sorbed and the relative humidity of the environment. At equilibrium, water activity is related to the relative humidity of the surrounding atmosphere by equation:

\[
a_w = \frac{p}{p_o} = \frac{\% \text{ Relative humidity}}{100} \tag{1}
\]

where \( p \) is the vapour pressure exerted by the food material, \( p_o \) is the vapour pressure of pure water at temperature \( T_o \) and \( T_o \) is the temperature of the system.

On the basis of the Van der Waals adsorption of gases on various solid substrates reported in the literature, Braunauer et al., (1940) classified adsorption isotherms into five general types. Moisture sorption isotherms of most foods are nonlinear, generally sigmoidal in shape and have been classified as type-II isotherms. Another behaviour commonly observed is that different paths are followed during adsorption and desorption process, resulting in a hysteresis. The desorption isotherm lies above the adsorption isotherm and therefore more moisture is retained in the desorption process compared to adsorption at a given equilibrium relative humidity.

The isotherms can be subdivided into three zones each representing a different mechanism for water sorption. In zone C, which corresponds to higher water activities, the influence of insoluble solids on water activity is negligible. The water activity is dependent upon the solute and the water content of the solution phase. In zone B, which corresponds to intermediate water activities, the influence of insoluble solids on water activity becomes significant. The isotherm flattens out and very small changes in moisture content are reflected by very large changes in water activity. In this zone, water is held in the solid matrix by capillary condensation and multilayer adsorption. Zone A, which corresponds to low water activities, represents adsorption of water on the surface of solid particles. None of the water is in liquid phase. The heat of vaporization of water in this zone is higher than the heat of vaporization of pure water since both heat of vaporization and heat of adsorption must be supplied to remove the water molecules from the solid surface.

The adsorption and desorption isotherms of an Indian dairy product ‘khoa’ at 25°C as reported by Sawhney et al., (2000) are sigmoid shaped of type-II according to B.E.T. classification and the hysteresis effect extends over the entire range of water activities. The initial water activity of khoa is 0.96. There is a steep fall in the equilibrium moisture content of khoa with decrease in relative humidity upto 85%. Between the water activities 0.25 to 0.60 the equilibrium moisture content of khoa remains almost constant. The hysteresis effect in khoa was moderate for the water activities less than 0.1. It increased at higher water activities and occurred predominantly in the water activity range of 0.35 to 0.65. The hysteresis effect diminished beyond 0.8 water activity and the adsorption and desorption isotherms of khoa coincided with each other at water activities above 0.96 at 25°C.
4.0 ISOTHERM EQUATIONS

A large number of equations have been derived to describe the relationship between water activity and moisture content of foods. Since water is associated with a food matrix by different mechanisms in different activity regions, no sorption isotherm model seems to fit the data over the entire water activity range (Labuza 1975). Some of the MSIs are therefore described by semi empirical equations with two or three fitting parameters. The B. E. T. isotherm equation (Brunaner *et al*., 1938) is a most widely used model and gives a good fit to data for a variety of foods over the region $0.05 < a_w < 0.45$. The B. E. T. equation is generally expressed in the form

$$\frac{a_w}{X(1-a_w)} = \frac{1}{X_mC} + \frac{C-1}{X_mC} a_w$$

where $a_w$ is the water activity, $x$ is the equilibrium moisture content (g water/100 g solids), $X_m$ is the mass fraction of water equivalent to monolayer of water covering the surface of each particle. $C$ is a constant at constant temperature and is related to the heat of adsorption of water on the particles. $C$ is temperature dependent.

A detailed collaborative study of water activity of foods undertaken by the European Economic Community in the project titled COST-90 recommended the Guggenheim-Anderson-de Boer (G.A.B.) model for wider range of water activities. The G.A.B. expression may be written as:

$$\frac{a_w}{W} = \frac{K(1-C)}{W_mC} a_w^2 + \frac{C-2}{W_mC} a_w + \frac{1}{W_mC k}$$

where $W$ is the equilibrium moisture content, $W_m$ is the moisture content equivalent to monolayer value and $C$ and $k$ are the constants.

Sawhney & Cheryan (1988) applied the B.E.T. equation to moisture sorption isotherm of khoa and found an excellent fit in the water activity range 0.11 to 0.43. The $X_m$ and $C$ values of khoa have been found to be 2.978 g water/100 g solids and $-29.2$ respectively at 25°C. Sawhney *et al*., (1989) evaluated various models for describing moisture sorption in khoa and reported that the data for khoa fits well to G.A.B. expression upto a water activity of 0.9. The G.A.B. parameter for khoa have been found to be $W_m$, 3.419; $k$, 0.84; and $C$, $-74.05$ at 25°C.

5.0 TEMPERATURE DEPENDENCE OF WATER ACTIVITY

The knowledge of the temperature dependence of sorption phenomenon provides the valuable information about the changes related to the energetics of the system. The constants in MSI equations, which represent either temperature or a function of temperature are used to calculate the temperature dependence of water activity. The Clausius-Clapeyron equation is often used to predict water activity at any temperature if the isosteric heat and water activity values at one temperature are known. The variation in water activity with temperature could thus be predicted by incorporating temperature terms into sorption equation. Sawhney *et al*., (1991)
determined temperature dependence of G.A.B. constant of khoa by drawing up isotherms of the product at 15, 25, 35 and 45°C, in the following form:

\[
W_m(T) = 0.0306 \exp \left( \frac{11.561 \times 10^3}{RT} \right)
\]

\[
C(T) = 0.172 \exp \left( \frac{15.54 \times 10^3}{RT} \right)
\]

\[
k(T) = 2.9669 \exp \left( -\frac{3.062 \times 10^3}{RT} \right)
\]

The equations (4)-(6) together, with equation (3) can be used to calculate the equilibrium water content \( W(T) \) of khoa at any given water activity and temperature by means of GAB \( T \) constants.

A survey of literature data on the effect of temperature on different food products shows that the monolayer moisture content decreases with increasing temperature. The extent of decrease, however, depends upon the nature of foods. In khoa, the monolayer moisture content values (in GAB equation) decreased from 3.89 at 15°C to 2.46 g water/100 g solids at 45°C. This relative effect of temperature on monolayer moisture content is important in dehydration shelf life simulation and storage studies.

6.0 WATER ACTIVITY AND REACTION KINETICS OF FOOD DETERIORATION

The primary reactions which affect food quality and stability include, autoxidation fatty acid hydrolysis, oxidation, enzyme reactions, non enzymatic browning and microbiological proliferation. The rate of deterioration of a food can be represented by a simple zero or first order reaction of the following form (Labuza, 1980)

\[
\frac{dA}{d\theta} = k_o e^{-\frac{E_a}{RT}} [A]^n
\]

where:

- \([A]\) = amount of quality factor
- \(\pm \frac{dA}{d\theta}\) = rate of loss of quality factor for production of undesirable effects
- \(k_o\) = pre-exponential factor
- \(E_a\) = activation energy (cal/mole)
- \(R\) = gas constant (cal/mole°K)
- \(n\) = reaction order

The water content and water activity of foods influence \(k_o, E_a, [A]\) and \(n\). At the monolayer moisture content the water is tightly bound and can not act as aqueous phase reaction medium. The rate of reaction is so slow as to be negligible in terms of food storage stability. Just above the monolayer, the solutes can become mobile but their movement is slow. As the water activity further increases the phase viscosity decreases and a rapid mobilization is evident. These factors influence the \(k_o\) and \(E_a\) by increasing or decreasing them. Another major effect of water activity on reaction rate could be the change in order of reaction. The influence of water activity...
on a particular quality index of the food product needs to be evaluated individually as well as synergetically. The relationship between stability based on summation of the series of independent and/or interdependent chemical reactions is then characterized to work out the water activity optima for a given food.

7.0 WATER ACTIVITY AND PREDICTION OF SHELF LIFE OF FOOD PRODUCT

Shelf life of foods depends upon a large number of factors such as temperature, equilibrium relative humidity, oxygen partial pressure, light, package permeabilities and package configuration. Some of these factors remain constant during storage while others change such as equilibrium relative humidity and oxygen partial pressure. It is necessary to determine which are the particular factors responsible for the eventual unacceptability of the product. The rate of change of moisture content of the product is a function of rate of moisture transfer through the package as given by the following equation.

\[
\frac{dm}{dt} = \frac{AkWPWS}{XW} (a_o - a_i)
\] (8)

where:

- \(m\) = moisture content of the product (g/g solids)
- \(kW\) = water vapour permeability (g mil)/ m² hr mm hg)
- \(PWS\) = pressure of saturated vapour
- \(a_o\) = water activity outside of package
- \(a_i\) = water activity inside of package

This equation may be solved if the relationship between moisture content and the water activity is known. For example, a food product may give the best fit isotherm equation in the following form

\[
m.100 = \frac{P_1}{\ln(a_i)} + P_2
\] (9)

where \(P_1\) and \(P_2\) are empirical constant. It is convenient to describe the shelf life of food in the product in the following dimensionless variables:

\[
Y = \frac{RH}{RH_{max}}
\] (10)

where \(RH_{max}\) is the maximum allowable equilibrium relative humidity of the product. Substituting these values and equation (9) into the differential equation (8) and noting that \(RH = a_i.100\) and \(RHO = a_o.100\), we obtain

\[
\frac{d(y)}{dt} = \frac{Y.RH_{max}}{-P_1} \left[ \ln \frac{Y.RH_{max}}{100} \right]^2 \left[ \frac{A.KW.PWS}{X.W} \right] \left[ \frac{RHO}{RH_{max}} - Y \right]
\] (11)
To obtain $Y$ as a function of time the above differential equations has to be solved which could be done with a suitable computer programme to a high degree of accuracy.

8.0 WATER ACTIVITY ADJUSTMENT IN FOODS

Control of moisture in processing of foods is an established method of preservation. It is now well accepted that the shelf life of foods can be extended considerably by adjusting the water activity to below 0.85 (Leistner, 1976). Humectants such as salt, sugars, glycerol and propylene glycol can be added to the food system to develop more favourable water sorption isotherms (Karel, 1976). In addition to their ability to bind water, some humectants also exhibit other desirable effects in food system as a result of their antimicrobial properties, sweetening capacity and texturizing characteristics (Labuza et al., 1974). Humectants which reduce the water activity of food without adversely affecting their taste and rheology, greatly improve the marketability of the foods by extending their shelf life.

Modification of water activity of heat concentrated whole milk product ‘khoa’ with addition of humectants has been attempted by Sawhney et al., (1992). The water activity of freshly made khoa is 0.96. (Sawhney and Cheryan, 1988) which is optimal for growth of most of bacteria and mold. The water activity of khoa could be reduced to 0.846 by addition of 30% sucrose (Sawhney et al., 1992), 0.91 by addition of 4% glycerol (Sawhney et al., 1994) and 0.931 by addition of 4 % propylene glycol (Sawhney et al., 1990). Synergistic effect of different combinations of various humectants was studied by Sawhney et al., (1997) to evaluate the sorption characteristics, product acceptability and stability in terms of rheological characteristics, microbiological growth rate and sensory evaluation. The samples adjusted to 0.866 water activity with a humectant combination of sucrose, starch and glycerol have been reported as most acceptable and stable. In addition to the lowering of water activity by using humectants, the shelf stability of the food product could further be enhanced by using other additives in conjunction with the humectants provided the regulatory and safety aspects are satisfied.

9.0 REFERENCES


1.0 INTRODUCTION

Aseptic processing technology is one of the most extensively exploited methods of food preservation. UHT milk, followed by pasteurised fruit juices, were among the first commercially successful products to be sold in modern flexible and semi-rigid packaging materials. It is in the continued use of these and their new applications for other foods to which the main advantages relate in terms of economy, convenience and lightness, especially so when compared with the packaging alternatives such as metal cans or glass jars.

Aseptic processing is a continuous system and involves pumping the product to heat exchanger, heating, holding for fixed duration in holding tube, flash cooling in heat exchanger followed by packaging in a neat and sterile containers. The concept of aseptic processing has been successfully adapted in dairy and food industry for liquid processing not only because of its inherent advantages over conventional sterilization but also due to elimination of the post processing cost of refrigerated storage and distribution besides producing products of long shelf life. Over the past few decades, considerable research in the field has led to the development and design of new equipments and processes for aseptic processing and packaging of milk and particulate foods.

2.0 UHT HEATING SYSTEMS

Long life milk obtained by ultra high temperature treatment became a reality with the advent of high heating plants and aseptic packaging systems. The commercial can filling systems of James Dole Engg. Co (USA) and the form-fill-seal system for carton filling developed by A.B. Tetrapak (Sweden) marked the beginning of the era of aseptic processing of liquid milk. Even more spectacular was the development of direct-steam heating systems such as Uperiser (Alpura, Switzerland) and Palasisator (Pasila, Denmark) that led to aseptic processing of milk on commercial scales. Subsequent to their invention, these equipments have undergone considerable improvements to enhance their efficiency, although little has changed in respect of their basic design.

UHT processing of milk refers to heating to 135-150°C for 2-10 s. These high temperatures and short holding times necessitate that the equipment is so designed as to meet these conditions. There are two major types of steam/hot water-based continuous-flow UHT processing systems: (a) Indirect-heating and (b) Direct-heating.
2.1 Indirect heating systems

Heating of milk to the sterilizing temperature can be achieved in heat exchangers based on corrugated plates, tubes or scraped-surface cylinders allowing heat exchange between the heating medium and milk, or hot milk and cold milk. The important requirement of these plants is that they should be able to withstand the high internal pressures building up at the processing temperatures. The extent of regeneration determines their energy efficiency.

2.1.1 Plate-type UHT plants

This system is, in principle, similar to the plate-type pasteurizer. However, the plate-sealing gaskets made of compression rubber or plastics are specifically selected to function under high internal-pressure conditions. Homogenizer is located between the first and second regenerators. The heating section is provided with steam or pressurized hot water as the heating medium. A back-pressure valve (up to 300 kPa) provided in the cooled-milk line i.e. at the end of regenerators or the cooler prevents boiling of milk at the sterilizing temperature. If desired, a deaerator may be placed between the regenerator or before the final heating section.

Regeneration up to 95% is possible in plate heat exchangers (PHE) employed in UHT systems. Sometimes, milk-to-milk regeneration is substituted with milk-to-water and water-to-milk regeneration by providing an intermediate closed water circuit which may also be designed to include the hot water line of the final heating section. Alfa-Laval's Steritherm and APV Pasilac's SIH (Sterilizer, Indirectly Heated) are examples of the plate-type UHT system.

2.1.2 Tubular UHT systems

Single tubes coiled in a chamber filled with the heating (or, cooling) medium (Sterideal of Stork, Holland and Monotube of Alfa-Laval; double concentric tubes with milk in the inner tube (Sweden, Cherry Burrell, USA), and triple concentric tubes with milk in the middle and heating medium in the inner and outer tubes are some of the designs of the tubular UHT system. Multitubes consisting of a tube bundle in a shell (Multitube of Alfa-Laval and multiple concentric tubes with 4-8 channels of corrugated tubes, one inside another (Spiraflo Multichannel of Alfa-Laval) are among other specialized tubular UHT plant designs. While double-tube heat exchangers are suitable for regeneration, triple and multiple-tube systems are particularly suited to steam heating to the sterilizing temperature.

While high velocities of the heat exchange fluids are necessitated for efficient heat transfer in tubular heaters, corrugations of tubes in certain systems provide the requisite turbulence as well as strength to the tubes. The tubular systems are capable of withstanding high internal pressures. A regeneration level of 85-90% is common in these systems.

2.1.3 Combined plate and tubular heating systems

Plate heat exchangers in the lower temperature sections and tubular configuration for the final heating help combine the merits of the two designs in a single UHT system (Schmidt, Germany; APV, Denmark).
2.1.4 Scrapped Surface Heat Exchangers (SSHE)

Primarily suitable for viscous-fluid handling, the SSHE system provides continuous scraping of the product from the cylindrical heat exchange surface while the product enters the jacketed cylinder from one end and exits from the other. A three-cylinder thin-film horizontal SSHE unit has been designed and fabricated at this institute for UHT treatment of milk, among other applications. The 'Contherm' (vertical cylinders) system of Alfa-Laval is a commercial SSHE-type plant. The SSHE systems are, however, not only more expensive but also pose a problem of ineffective regeneration. A unique feature of the thin-film SSHE is that there is very little pressure drop, unlike in case of tubular and PHE systems.

2.2 Direct-heating UHT Systems

The major difference between the indirect and direct heating systems is in respect of the time-temperature profile. The residence time for milk at temperatures above 100°C is appreciably reduced in the direct system. Thus the severity of the heat treatment is lower when milk is heated by direct steam incorporation. Direct heating is achieved either by (a) injection of steam into milk or (b) spraying of milk in
a steam filled chamber (‘infusion’), but in both the systems milk is preheated to 80-100°C by indirect methods.

2.2.1 Steam injection

Heating by the 'steam-into-milk' process is achieved in Alfa-Laval's VTIS (Vacu-Therm Instant Sterilizer), APV's Uperiser, Stork's Steritwin and a few other systems. Preheating of the milk takes place through regeneration, use of hot water or vacuum steam, or a combination of two or more of these. Milk is delivered at about 500 kPa into the steam injector designed to give maximum stability of the temperature and pressure desired during operation and the minimum effect of build-up solids within the injector. The diluted milk (i.e. milk-condensate mixture) at the sterilizing temperature flows through the holding tube and then sprayed into an expansion chamber maintained under a definite vacuum. There, not only instant cooling of milk is effected but also the excess water added in the form of steam is removed by vaporisation. The partially cooled milk is removed by an aseptic pump, homogenized in an aseptic homogenizer and then cooled by regeneration to the final temperature. The vapours removed from the flash chamber are condensed in a water jet condenser which may be used as a regenerator as well. Alternatively, an indirect (plate-type) water-cooled condenser may be employed and the cooling water circulated through a plate-type regenerator for preheating of milk.

The 'downstream' location of the homogenizer in the direct-heating systems is needed to minimize, certain texture defects. Also, fat tends to agglomerate upon direct heating of previously homogenized milk. The homogenizer is made 'aseptic' by providing steam seals.

2.2.2 Steam infusion

The 'milk-into-steam' (‘Infusion’) process uses a steam infuser as the final heating section. Milk entering this steam vessel is heated as it falls to bottom. The milk at sterilizing temperature is removed from the steam pressure chamber by another positive displacement pump which transfers the product to the expansion chamber. Other features of this system are similar to those of the injection system. A variable speed aseptic homogenizer following the expansion vessel ensures, in conjunction with a level controller, a definite milk level in the vessel. The Laguilharre (France), Ultratherm of Crepaco (USA) and Palarisator of Pasilac (Denmark) are among the commercially available infusion systems. The Falling Stream Heater (FSH) developed by DHE (Den Hollander Engineering, Netherlands) is an infuser system for achieving temperatures up to 160°C and a correspondingly very short holding time (e.g. 0.7 s).

2.3 Control systems for UHT plants

Temperature control is the most important for any UHT system. In indirect systems a temperature-sensing element in contact with the heated milk activates, through a controller, the raising or lowering of the heating medium's temperature. A flow diversion valve (FDV) is used as a safety mechanism to prevent undertreatment of milk. The underheated product, upon diversion, is cooled before being returned to the balance tank for reprocessing. Visible and audible signals may also be activated
if the temperature falls below the present level. Automatic change to water processing upon undesirable temperature fall prevents further processing without correction of the fault.

The milk flow rate is essentially determined by the upstream homogenizer in indirect systems. A variable speed homogenizer may be used to vary the throughput if so desired from the view point of filling requirements. When a deaerator is provided, equal rates of milk supply to and removal from the vessel are maintained by various means depending on the supplier of the system.

Direct heating systems require more complex control devices than those for indirect systems. Besides the final temperature control, the temperature of the milk prior to steam incorporation and after vacuum evaporation need to be controlled so that effective composition control is achieved. A system of level control for milk in the expansion vessel is equally important. Such a control is more critical in case of the steam infusion process because of the presence of a steam chamber (infuser) in addition to the vacuum chamber. When FDV is used, a second expansion chamber in the diversion line becomes imperative to keep the milk composition unaltered. The product temperature control required for controlling the product composition after vacuum evaporation may be effected by (a) holding the vacuum in the expansion chamber constant and varying the preheating temperature by the temperature controller, or (b) keeping the preheat temperature constant and varying the vacuum. Vacuum variation may, however, cause a carry-over of milk into the vacuum line and affect composition control.

2.4 Aseptic processing of particulate foods

For many years, food processors have tried to develop an aseptic process for food product containing particles but development of such a process has been hindered by the requirement to demonstrate an adequate thermal treatment for every portion of the product. A major concern in the processing of low-acid foods (pH > 4.6) is the assurance of microbiological safety of the final product. Certain traditional dairy products also falls in this category such as milk-rice or Kheer of different types. Since these products can under anaerobic conditions, support the growth of Clostridium botulinum, the thermal process provided to the food product must be sufficient to render all parts of the product (including the interior of the food particles) commercially sterile.

Heat transfer to homogeneous systems, or fluid food products without particulates, is effected by convection if the food is adequately agitated, as happen during scraped surface heat exchangers. However, the situation is very different for heterogeneous systems, or food products containing particulate material. The heat transfer to the continuous or liquid phase that surrounds the particles still occurs by convection, but the penetration of heat into the solid particulates occurs by conduction, which for food is generally a much slower process.

This results in the occurrence of a considerable time lag for temperature increase within the particles, as compared to the surrounding liquid. By the time that enough heat has penetrated to the centre of the particles to ensure destruction of micro-organisms or spores, the continuous or liquid phase has been exposed to much more heat than is necessary to ensure safety in that phase.
The main factors which affect the minimum process required for achieving satisfactory sterility levels for particulates being heated in a fluid are:

- Initial temperature of the product
- Physical properties of the particulates and the effect of temperature
- Shape and dimensions of the particulates
- Particulate loading
- Processing temperatures such as heat-hold-cool
- Flow rates, flow regimes and residence times
- Wall to liquid and liquid/particulate heat transfer coefficient.

2.4.1 Aseptic particulate food processing systems

A number of commercial systems have been devised for aseptic processing of particulate foods. They include:

2.4.1.1 Plate heat exchanger (PHE)

These heat exchanger systems are suitable for processing homogenous, low viscous foods containing very small particles.

2.4.1.2 Free flow heat exchanger

These systems are very much similar to PHE in design except that they do not have regular distribution of supporting points across the surface. The annular space in the free flow heat exchanger decides the particle size of particulate foods being processed.

2.4.1.3 Tubular heat exchanger

These heat exchangers are suitable for processing particulates with size of about 1/4th of the tube diameter. These are beneficial in terms of having minimum effect on particle integrity but requires large heat transfer surface that increases with increase in particle size.

2.4.1.4 Scraped surface heat exchanger (SSHE)

This is a scaled down agitating vessel, which favours continuous sterilization of particulates. The size of the particle that can be handled is limited by the annular gap (max 15 mm) between the agitating blades and inner heat exchanger surface. These are conducive for handling high viscous foods. The only drawback is the effect on particle integrity. It could be prevented by either increasing the viscosity of the working fluid, change in design configuration adjusting the gap between the blades and inner heat exchanger surface, varying the rotor diameter, suspending scraper in various configurations (fixed/variable clearance) and standardizing the process parameters during operation.
2.4.1.5  *Patricon process*

This process involves use of SSHE with slight modifications in design for processing of particulate foods with large size particles. It is capable of processing delicate solids upto 3.8 cm in diameters.

2.4.1.6  *Stork-steripak system*

This system consists of holding tube device called Rota-hold which is a cylindrical vessel with baffles mounted on a central rotatable shaft inside along with inlet and outlet ports. By varying the RPM of baffles, the residence time of particles in the system could be varied. Presently, Rota-hold units have been used for handling particulates of size upto 20 mm.

2.4.1.7  *Jupiter double cone heat exchanger*

Particulate processed with the above configurations have encountered some problems in terms of particle integrity and extension of thermal effects on quality of liquid. This could be averted by processing solids and liquids separately which is the concept involved in this system. The system is so designed that, liquids are sterilized using a suitable heat exchanger and particles are sterilized in double-jacketed cone type heat exchanger and at the end both are blended together before packaging aseptically. The double cone system is usually rotated so as to get uniform heat treatment in particles. This system could be used for processing particulate foods with large sized particles.

2.4.1.8  *In-drum sterilization system*

This system comprises of lacquered drum in which particles are filled, followed by circulation and reheating of hot syrup into drum, till sterilization process is completed.

2.4.1.9  *Steriglen process*

This process involves use of fluidized bed to heat under pressure, hold and cool the product using gravity.

2.4.1.10  *Multitherm process*

This process involves application of microwaves for sterilization of particulate foods that are pre-packed. The frequency ranges that have been used for particulate food processing ranged from 896 to 2,450 MHz both under pressurized and non-pressurized conditions.

2.4.1.11  *Ohmic system*

The Ohmic heater is a new development which provides an excellent alternative to tubular and SSHEs for aseptic processing of viscous and particulate food materials.
3.0 ASEPTIC PACKAGING OF MILK

Although both the aseptic can filling and aseptic carton filling systems became commercial during the late fifties and early sixties, only the latter found application in aseptic packaging of UHT milk. During the past few years, environmental considerations have led to the use of recyclable glass bottles instead of cartons in countries like Germany.

The major requirement of an aseptic packaging unit is to prevent recontamination of the sterilized milk. The principal considerations in this regard include sterilization of the filling machine and packaging material by suitable physical and/or chemical means and maintaining aseptic barriers during filling and sealing. Besides the equipment and packaging, gas used to pressurising the filling space is one of the sources of recontamination of milk. Thus mechanical failures such as inadequate heating of the gas, leaks in valves and pin-holes in filters may cause recontamination and must therefore be checked.

3.1 Sterilization of the packaging and the filler environment

Chemical sterilization processes for the packaging film include treatment with ethylene oxide, sodium hypochlorite, peracetic acid and hydrogen peroxide (H$_2$O$_2$). Ethylene oxide is not only slow in action but its desorption requires very long time. Hence it can be used for pre-treatment of packaging, but not for final sterilization on the packaging unit. Sodium hypochlorite and peracetic acid are very effective sterilants, but removal of their residues from the packaging necessitates a sterile-water rinse. Alcohols such as glycols require high temperature (e.g. 100°C) application for the desired sporcidal effect. Although H$_2$O$_2$ also shows poor effectiveness at ambient temperatures, its high sporcidal effect at 80°C makes it useful for packaging sterilization. It is first applied on the material and then evaporated by heating through hot air or infra-red radiation. The limitations of the use of H$_2$O$_2$ are: (i) the surfactant(s) or wetting agents used for uniform deposition on the packaging film, cannot be evaporated by heat and thus may find their way into milk, (ii) the vapours of H$_2$O$_2$ must be exhausted to avoid injury to the workers, and (iii) the efficacy of its removal by evaporation must be monitored through routine testing of milk.

While steam or hot water is effective in sterilization of the milk carrying tubes, hot air (300°C) with or without filtration, is commonly used for sterilization of the air injected in the filling space. Air at 330-350°C (for 30 min) may also be used for milk tube sterilization. Sterilized air reduced to 180-200°C is used to evaporate H$_2$O$_2$ and when cooled to 50°C can be employed for pressurizing the filling chamber.

Effective use of UV radiation imposes certain stringent requirements such as perpendicular incidence of rays, dry atmosphere, smooth surface, low concentration of microorganisms, absence of visible light to avoid reactivation of microorganisms and shields to protect the operator. Therefore, UV radiation is suitable only for a complementary treatment of already sterilized packaging. Filtration by means of depth filters (mats of compressed glass- or asbestos- fibre, or of sintered metal or ceramic) is effective in freeing air from bacteria. The filters themselves may be sterilized by fumigation, hot air or steam.

Aseptic barriers in the form of steam or circulated liquid sterilant become necessary with valves and fittings coming in contact with sterile milk. Detection of
leakers by using a dye test is imperative to check recontamination of the packaged sterile milk.

### 3.2 Aseptic packaging systems

Filling of commercially sterile milk in sterilized packages/containers in a sterile environment, and hermetically sealing the same to prevent recontamination of the milk can be achieved in two major ways: (a) using presterilized preformed containers such as bottle and cans, and (b) sterilizing the packaging material, forming it into suitable containers, filling the sterile product and sealing the package on the so-called form-fill-and-seal (FFS) machines. The latter employs a multiply laminate of polyethylene, polystyrene and/or polypropylene films, paper and aluminium foil.

The Dole aseptic canning system has been used for UHT milk in the USA, but only to a limited extent. The most widely used FFS Tetra Pak systems using tetrahedron cartons, and Tetra-Briks or hexahedron cartons are characterized by continuous formation of the package below the milk level from a paper/PE/Al laminate strip which has been continuously sterilized by $\mathrm{H}_2\mathrm{O}_2$ boiled off by radiant heat in the region immediately above the milk surface thus giving a sterile atmosphere in the packaging zone. Recently Tetra Pak has introduced the so-called 'Pillow Pak' to cut down the packaging cost of UHT milk.

Several other FFS systems have been developed which include Thimonnier (France) and Prepac (France) cushions or pillows. Pure-Pak (USA) and Combibloc (Germany) rectangular bricks are formed from paperboard/laminate blanks, then filled and sealed. Blow-moulded polyethylene bottles such as Rommelag's Bottle-pack (Switzerland) and Remy's Total Pac (France) have been used for packaging of UHT milk in the UK.
Systems for aseptic filling of UHT milk in drums (No-Bac 55, USA), pails (Dole, USA) and bag-in-box (Gaulin, Scholle; USA) have also been reported. UHT milk has been filled aseptically in a sterile SS tank and successfully transported over long distances in the UK.

4.0 COUPLING OF ASEPTIC PACKAGING WITH THE UHT PLANT

In small processing units, a single flow-sterilizing plant can be connected with a single packaging plant of the matching capacity. But this system is inflexible because both the sterilizer and filler must operate simultaneously. If one stops for any reason, the other must be shut down, or in case of the filler stopping, the sterilized milk must be recirculated for reprocessing. This problem can be solved by providing an aseptic tank at the interface between the two plants.

In large units, it is a general practice to feed two or more fillers from a single sterilizing plant whose capacity is equal to the total of filling capacity. So, if one of the fillers has to be shut down only a small portion of UHT milk will be required to be recycled. Use of a variable speed homogenizer can altogether eliminate the need of recirculation of sterilized milk in such a situation. Even with a multiple filler system, aseptic tank is very useful for smooth operation of the whole system without jeopardising the product quality. Aseptic balance tank, however, adds to the investment cost as well as cleaning and sterilization requirements. It also requires a supply of sterilized air for partial positive pressure during its use.

5.0 CONCLUSION

Both direct and indirect heating systems of UHT processing are used in the western countries especially in Europe. Direct systems permit rapid heating to the sterilizing temperature so that the residence time is reduced and product quality improved. Recently, a steam infusion process has been reported to give temperatures up to 160°C with holding time as short as 0.7 s. However, direct systems are not only expensive, but also require special attention because of involved controls. The need of culinary steam for direct UHT plants also increases the costs of initial investment as well as operating costs. Hence, indirect plants are often preferred. Under the Indian situation, experience has shown that the indirect systems, especially tubular ones perform satisfactorily. Although somewhat more expensive than the plate-type UHT system, the tubular plant poses less problem of pressure drop due to deposit formation and is easy to clean and maintain. It also gives reasonably high regeneration (80-90%) and so, high processing (or energy) economy. Both the coiled tube (Stork) and multitube (Alfa-Laval) systems have been successful in India. Packaging of UHT milk has been dominated by the Tetra-Brik form-fill-seal system the world over.

Recent introduction of the Pillow Pak by Tetra Pak has resulted in some cost reduction but further innovations towards this goal will have far-reaching implications in popularizing UHT milk in India. It may, however, be noted that a 2-stage HTST sterilization process (Alstom, France) for long-life milk involving first-stage UHT heating followed by second-stage in-bottle sterilization has been reported to do away with aseptic packaging and appreciably reduce the total operating cost.
In the Indian context, UHT technology has proven its potential in respect of fluid milk. But for its successful commercial adoption a few problems remain to be solved. The advent of a wide range of processes capable of producing even viscous and particulate UHT products offers the dairy industry a great opportunity to expand its market base. The engineering and technological advances made in the recent past can be of considerable help in extending the ‘long life’ benefits from fluid milk to other products like concentrates, cream, desserts etc. With this the Indian dairy industry now engaged in product diversification, value addition and export promotion is uniquely placed to exploit these benefits.

Over the past few years, the concept of aseptic processing is being explored for particulate food processing. Extensive research in understanding the heat transfer phenomenon, hydrodynamics, thermal process calculation concepts and microbial verification of particulates have been conducted. Further, mathematical modeling and computer simulation are also being applied to have a better understanding of the above concepts and for marketing as aseptically processes products. The future of aseptic particulate food processing on industrial scale and its commercialization depends upon generation of the critical information.

6.0 REFERENCES

INTRODUCTION

Man has been drying food to preserve it since the beginning of recorded history. This ‘art of living’ has depended mainly on sun and air, making it hard to get uniform quality. Nevertheless, this natural method has remained popular for preserving food for a long time. As a result of severe shortcomings, these conventional methods began to be replaced by more efficient mechanical methods. It was not until the turn of the 20th century that mechanical drying finally began to replace natural sun drying. Modern methods of drying of foods include drum drying, spray drying, flash drying, freeze-drying, microwave drying and more recent methods are fluidized bed and integrated belt drying. Food drying involves simultaneous heat and mass transfer. The quality of dried foods are influenced by time and temperature used in the drying process. This necessitates careful selection of dryers and drying methods suitable for tailor-made products.

Special technologies have been evolved over the years to manufacture products with improved functional properties such as instant products, high water binding products and products with high bulk density (to save shipping volume). This lecture will mainly deal with some of the advances made in the area of spray as well as fluidized bed drying as applied to drying of foods.

NEED FOR ADVANCES AND INNOVATIONS IN DRYING

As an operation of pre-historic origin, one would normally not associate drying with innovation and any further advances. Still R&D activity in drying has been escalating rapidly over the past two decades. Some of the factors, which might justify need for constant innovation and advancement in drying can be easily summarized as under:

- New product or process not made or invented so far
- Higher needed capacities than current technology permits
- Better quality and quality control than currently feasible
- Reduced environmental impact
- Safer operation
- Better efficiency (resulting in lower cost)
- Lower cost (overall)
3.0 APPLICATION OF DRYING TO FOODS

Drying has been used for a vast number of foods. To elucidate this point following examples are given below, though the list is not exhaustive.

- **Beverages/Food flavours**: chocolate, coffee, meat, mustard, paprika, spices, soy, tea
- **Dairy foods**: baby food, butter, buttermilk, casein, casienate, cheese, cream, fat filled whey, lactose hydrolyzed whey, permeate, skim milk, sweetened condensed milk, traditional dairy products (*khoa* powder, *gulabjamun* mix powder, *lassi* powder, *kheer* mix powder etc.), whey, whole milk, yoghurt
- **Flour**: bakery mix, cereal baby food, sauce base, tomato soup base
- **Fruits/vegetables in pulp form**: apple, apricot, asparagus, avocado, banana, carrot, coconut, cranberry, onion, orange, strawberry, tomato
- **High fat powder ingredients**: butter, fish oil, lard, lecithin, tallow, vegetable oil
- **Natural sweeteners**: glucose, honey, malt extract, maltodextrin, molasses, sorbitol
- **Protein foods**: egg, fish extract, hydrolyzed vegetable protein, hydrolyzed yeast extract, meat extract, whey protein concentrate

4.0 CONVENTIONAL VERSUS NEW DRYING TECHNOLOGIES

Many commonly used drying technologies have matured and perhaps reached their respective inherent limits of performance. Need for innovations because of the reasons enumerated above has resulted into numerous drying processes which are still evolving and are at different stages of growth and applications. An indicative account is presented below in Table 1 to depict the type of conventional and innovative dryers used for the same type of products.

**Table 1. Conventional versus innovative drying techniques**

<table>
<thead>
<tr>
<th>Feed type</th>
<th>Conventional</th>
<th>Innovative techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid suspension</td>
<td>Drum/spray</td>
<td>Fluid/spouted beds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spray/fluid bed combination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vacuum belt dryers</td>
</tr>
<tr>
<td>Paste/sludges</td>
<td>Spray/drum/paddle</td>
<td>Spouted bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluid bed with solids back-mix</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Superheated steam dryers</td>
</tr>
<tr>
<td>Particles</td>
<td>Rotary/flash/fluid bed</td>
<td>Superheated steam FBD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vibrated bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulsated fluid bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jet agglomeration dryers</td>
</tr>
</tbody>
</table>
5.0 SPRAY DRYING PROCESS

All the leading food-processing companies use spray dryers to produce powdered products. Spray drying process transforms a pumpable fluid feed into a dried product in a single operation. The fluid is atomized using a rotating wheel or a nozzle, and the spray of droplets comes immediately in contact with a flow of hot drying medium, usually air. The resulting rapid evaporation maintains a low droplet temperature so that high drying air temperatures can be applied without affecting the product. The time of drying the droplets is very short in comparison with most other drying processes. Low product temperature and short drying time allow spray drying of very heat-sensitive products. Some of the new developments in the area of spray drying are summarized below in Table 2.

Table 2. Some new developments in spray drying

<table>
<thead>
<tr>
<th>Developments</th>
<th>Key features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-in-filters</td>
<td>Powder confined to spray dryer chambers</td>
</tr>
<tr>
<td>Superheated steam spray dryer</td>
<td>High efficiency, quality adjustment</td>
</tr>
<tr>
<td>Low rpm rotary disk atomizer</td>
<td>Reduced power consumption, narrower size distribution</td>
</tr>
<tr>
<td>Multi-stage operation</td>
<td>Reduces size of drying chamber, internal water removed in small fluid or vibrated bed dryers, or through circulation conveyor dryer</td>
</tr>
<tr>
<td>Low pressure operation</td>
<td>Ultrasonic atomizer for monodisperse particles of heat-sensitive materials</td>
</tr>
</tbody>
</table>

5.1 Stages of spray drying

Spray drying of foods consists of three major process stages:

- Atomization
- Spray-air mixing
- Separation and collection of powder

Each stage is carried out according to the dryer design and operation and together with the physical and chemical properties of the feed, determines the characteristics of the final product.

5.1.1 Atomization

Atomization is the most important operation in the spray drying process. The type of atomizer not only determines the energy required to form the spray but also the size and size distribution of the drops and their trajectory and speed, on which the final particle size depends. The chamber design is also influenced by the choice of the atomizer. The drop size establishes the heat transfer surface available and thus the drying rate.
Three general types of atomizers are available. The most commonly used are the rotary wheel atomizers and the pressure nozzle single-fluid atomizers. Pneumatic two fluid nozzles are used only rarely in very special applications.

5.1.1.1 Pressure nozzles

A pressure nozzle, sometimes called a single fluid nozzle, creates spray as a consequence of pressure to velocity energy conversion as the liquid passes through the nozzle under pressure within the usual range of 5-7 MPa. The liquid enters the nozzle core tangentially and leaves the orifice in the form of a hollow cone with an angle that varies from 40° to 140°. When larger feed rate is to be processed, several nozzles are used in the drying chamber. Owing to their smaller spray angles the drying chamber can be narrower and taller. With this type of nozzle it is generally possible to produce the droplets within a narrow range of diameters, and the dried particles are usually hollow spheres. Pressure nozzles are not suitable for highly concentrated suspensions and abrasive materials because of their tendency to clog and erode the nozzle orifice.

5.1.1.2 Pneumatic nozzles

Pneumatic nozzles are also known as two-fluid nozzles since they use compressed air or steam to atomize the fluid. In this case the feed is mixed with the air, outside the body of the nozzle. The spray angle ranges from 20° to 60° and depends on the nozzle design. Approximately 0.5 m³ of compressed air is needed to atomize 1 kg of fluid. The capacity of a single nozzle usually does not exceed 1000 kg/h of feed. Sprays of less viscous feeds are characterized by low mean droplet sizes and a high degree of homogeneity. With highly viscous feeds, larger mean droplet sizes are produced but homogeneity is not as high. Pneumatic nozzles are very flexible and produce small or large droplets according to the air-liquid ratio.

5.1.1.3 Novel type of atomizers

A number of liquids that cannot be atomized successfully by wheels or nozzles have generated interest in using other methods of atomization that may be more suitable for such liquids. These are, for example, highly viscous and long molecular chain structured materials and some non-Newtonian liquids. Attention has been paid to the use of sonic atomizer. The disintegration of a liquid occurs in the field of high frequency created by a sonic resonance cup placed in the front of the nozzle. However, this development has not reached the stage at which sonic nozzles can be industrially competitive with other kinds of atomizers. They have some promising aspects, such as 15% savings in energy and applicability for abrasive and corrosive materials. The four main types of sonic atomizers are the Hartman monowhistle nozzle, steam jet nozzle, vortex whistle nozzle and mechanical vibratory nozzle.

5.1.2 Spray-air mixing

Concurrent flow mix pattern is used where low product temperature is needed. Mixed flow with integrated fluid bed pattern is commonly used for producing agglomerated powders. Yet another type of mixed flow pattern (fountain type) is for
coarse sprays in small chambers for non heat-sensitive products. Counter-current flow and mixing pattern is used for products, which withstand high temperatures, have coarse particles and for high bulk density powders.

5.1.3 Separation and collection of powder

Cyclone separators are the most commonly used separation systems when low cost, efficiency and cleanliness are the criteria. For a medium cost operation with high efficiency and high running cost, bag filters are used for powder separation. When dealing with separation of large air volumes, electro-static precipitators are used. A combination of cyclone and wet scrubber is used for better product and fines recovery.

5.2 Types of spray dryers – basis for selection

It is impossible to categorize all the dryer types that can be used to produce particulate products. Here we will focus only on the most commonly found dryers and compare them with some of the more recent and innovative drying technologies. As noted earlier, particulate products may be produced starting from a wet feed, which may have one of the following physical forms:

- Pumpable slurry/suspension/solution
- Thin/hard pastes or sludge
- Wet particulate solid

5.2.1 Drying of pumpable liquid feeds

Liquid-form starting materials are commonly dried to produce a free-flowing, low bulk density powder with a size distribution using a spray dryer, or to a higher bulk density, flaky product using a drum dryer. The basic concept of the spray dryer consists of atomizing the liquid into sprays of desired size and size distribution (depending on the types of atomizer, properties of the feed, etc.) and to expose it to a high temperature, unsaturated gas (hot air or direct combustion gases) in which the droplets are carried, dried and transported to a product collection device such as cyclone or bag house. The spray dryer chamber is sized to allow sufficient dwell time for the largest droplets to dry to the desired final moisture content. Among the less common dryers for slurries are fluid bed, vibrated bed or spouted bed of inert particle on which the liquid is sprayed into the bed and dried and pulse combustion dryers, where the slurry is fed as a jet (and atomized) into the exhaust tailpipe of a pulse combustor. The droplets dry ultra-rapidly due to the high temperatures and high relative velocities and turbulence.

5.2.2 Drying of pastes/sludges

An enormous choice of alternative dryers exists for this class of feedstock. A thin sludge can be hardened by back mixing it with dry product and even palletized prior to drying. It can also be diluted and dried in a spray or drum dryer. The choice often depends on the desired form of the final dried product. Drying in a fluid or
spouted bed of inert particles leads to a ‘dusty’ product due to the “milling” conditions in the drying bed. Such a product is not free flowing and is difficult to rehydrate. Some of the most commonly used multi-stage compact dryers being used for food products are shown below in Fig. 1.

![Commonly used spray drying configurations](image)

**Fig. 1** Commonly used spray drying configurations

### 5.2.3 Drying of wet particulate solids

The dwell time required is an important consideration in the selection of dryers for particulates. The key features of various dryer types are listed in the table along with some of the major limitations. This is not comprehensive but only illustrative. Often some of the advantages are offset by some limitations so the final choice is often a compromise. A brief idea of the type of dryers used for various types of feeds is presented in Table 3.

#### Table 3. Dryer types for production of engineered powders

<table>
<thead>
<tr>
<th>Technology</th>
<th>Feed</th>
<th>Product</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulsed combustion</td>
<td>Slurry</td>
<td>Powder</td>
<td>Very short drying times, can handle heat-sensitive materials</td>
</tr>
<tr>
<td>Heat pump</td>
<td>Particulates</td>
<td>Particulates</td>
<td>High efficiency, low temperature drying (less humid air)</td>
</tr>
<tr>
<td>Spray drying</td>
<td>Slurry</td>
<td>Powder</td>
<td>Monodisperse product using sonic/ultrasonic atomizers</td>
</tr>
<tr>
<td>Superheated steam drying</td>
<td>Particulates</td>
<td>Particulates</td>
<td>High thermal efficiency, no fire/explosion hazards</td>
</tr>
<tr>
<td>Pulsed fluid beds</td>
<td>Particulates</td>
<td>Particulates</td>
<td>Low-air/power consumption, can handle polydisperse materials</td>
</tr>
<tr>
<td>Impinging streams</td>
<td>Particulates</td>
<td>Particulates</td>
<td>High heat/mass transfer rates, small space requirements</td>
</tr>
</tbody>
</table>

### 6.0 FLUID BED DRYING

Fluid bed processing involves drying, cooling, agglomeration, granulation, and coating of particulate materials. It is ideal for a wide range of both heat sensitive and non-heat sensitive products. Uniform processing conditions are achieved by passing a gas (usually air) through a product layer under controlled velocity conditions to
create a fluidized state. In fluid bed drying, the fluidization gas supplies heat, but the gas flow need not be the only source.

Fluid bed drying offers important advantages over other methods of drying particulate materials. Particle fluidization gives easy material transport, high rates of drying at high thermal efficiency while preventing overheating of individual particles. Fluid bed drying is suitable for powders, granules, agglomerates and pellets with average particle size normally between 50 and 5,000 microns. Very fine, light powders or highly elongated particles may require vibration for successful fluid bed drying.

In fluid bed cooling, cold gas (usually ambient or conditioned air) is used. Conditioning of the gas may be required to achieve sufficient product cooling in an economically sized plant and to prevent pick up of volatiles (usually moisture). Heat may also be removed by cooling surfaces immersed in the fluidized layer. Agglomeration and granulation may be performed in a number of ways depending upon the feed to be processed and the product properties to be achieved. Fluid bed coating of powders involves the spraying of a liquid on to the fluidized layer under strictly controlled conditions. Fundamental principle of fluid bed granulation is shown in Fig. 2.

![Fig. 2 Functioning of a fluidized bed dryer](image)

### 6.1 Fluid bed types

There are two basic types of fluid bed designs according to the solids flow pattern in the dryer.

- The back-mix flow design for feeds that require a degree of drying before fluidization is established
- The plug flow design for feeds that are directly fluidizable on entering the fluid bed
6.1.1 Back-mix flow fluid beds

These are applied for feeds that are non-fluidizable in their original state, but become fluidizable after a short time in the dryer, e.g. after removal of surface volatiles from the particles. The condition of the fluidizing material is kept well below this fluidization point. Proper fluidization is obtained by distributing the feed over the bed surface and designing the fluid bed to allow total solids mixing (back-mix flow) within its confines. The product temperature and moisture are uniform throughout the fluidized layer.

6.1.2 Plug flow fluid beds

These are applied for feeds that are directly fluidizable. Plug flow of solids is obtained by designing the fluid bed with baffles to limit solids mixing in the horizontal direction. The volatile content and temperature vary uniformly as solids pass through the bed, and the plug flow enables the solids to come close to equilibrium with the incoming gas.

In plug-flow fluidized bed dryers the bed usually has a length-to-width ratio in the range of 5:1 to 30:1; the solids flow continuously as a plug through the channel from the inlet to the exit. This ensures approximately equal residence time for all particles, regardless of their size. The main operational problems occur at the feed end where wet feedstock must be fluidized directly rather than mixed with drier material as in a well-mixed unit.

6.1.3 Vibrating fluid bed dryer (VFBD)

For beds of particles, which are difficult, to fluidize due to strong polydispersity, particle size, or particle-to-particle adhesive forces (stickiness) it is worth considering a batch or continuous vibrated bed dryer. An application of nearly vertical sinusoidal mechanical vibration (half-amplitude 3-5 mm; frequency 10-50 Hz) allows “pseudo-fluidization” of the bed with rather low airflow rates. In this case, the requirements of hydrodynamics and heat/mass transfer are effectively coupled. Vibrated bed dryers can also be used to reduce attrition by gentle processing. Most vibrated fluidized bed dryers are continuous units.

This design, marketed under the name vibro-fluidizer, is basically of the plug flow type. It is especially applied for drying and cooling products that fluidize poorly due to a broad particle size distribution, highly irregular particle shape, or require relatively low fluidization velocities to prevent attrition. The vibro-fluidizer operates with a shallow powder layer of less than 200 mm. This gives a much lower product residence time per unit bed area than non-vibrating beds, which can have powder layers up to 1500 mm.

6.1.4 Contact fluidizers

This is a rectangular fluid bed dryer incorporating back-mix and mix flow sections. A rotary distributor disperses the wet feed evenly over the back-mix section equipped with contact heating surfaces immersed in the fluidized layer. The heating surfaces provide a significant portion of the required energy, and therefore, it is
possible to reduce both the temperature and the flow of gas through the system. This is particularly important for heat sensitive products. Subsequent plug flow sections are used for post drying and cooling, if required.

6.1.5 Batch fluidized bed dryers

Batch fluidized bed dryers are used for low throughput (normally <50 kg/h and good for 100 kg/h), multi-product applications. Drying air is heated directly or indirectly usually to a fixed temperature. The drying air flow rate is also usually fixed. However, it is possible to start drying at a higher inlet gas temperature and flow rate and lower it since the product moisture content falls below the critical value. Mechanical agitators or vibration may be needed if the material is difficult to fluidize.

6.1.6 Multi-tier fluid beds

These fluid beds consist of two or more stacked fluid beds. The upper tier (back-mix or plug flow) is for pre drying and the lower tier (plug flow) for post drying. The drying gas travels counter-current to the solids. The gas leaving the lower tier contains sensible heat, which is transferred to the upper tier. Furthermore, each fluid bed may be provided with immersed heating surfaces. These designs result in a low gas throughput and high thermal efficiency, which are of great importance in closed cycle drying systems. Various possibilities of combining fluid beds are presented in Table 4.

Table 4. Multi stage fluidized bed dryers

<table>
<thead>
<tr>
<th>Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similar FBD stages stacked one below the other</td>
<td>Reduce floor area/bed depth of each stage, low product moisture content possible</td>
</tr>
<tr>
<td>Flash dryer stage preceding FBD stage</td>
<td>Fast removal of surface moisture, reduced stickiness leads to easy production</td>
</tr>
<tr>
<td>Spray dryer stage followed by FBD stage</td>
<td>Significantly reduce spray dryer size</td>
</tr>
<tr>
<td>Well-mixed FBD followed by plug-flow</td>
<td>Ease of fluidization for high moisture</td>
</tr>
</tbody>
</table>

6.1.7 Continuous fluidized bed dryers (CFBD)

In this type of dryer, the bed temperature is uniform and is equal to the product and exhaust gas temperatures. However, due to inherent product residence time distribution, product moisture content will vary from the range from inlet moisture content to lower value. One advantage of the perfect mixing dryer is that the feed falls into a bed of relatively dry material and so is easy to fluidize.

6.1.8 Mechanically agitated fluidized bed dryers

Several designs of such dryers are in use today. For drying of pastes or sludges one variant uses a cylindrical vessel with a fast spinning agitator the bottom
on to which the feed drops by gravity for dispersion into an upward spiral of hot drying gas. Other versions use a high rpm chopper that disperses the feed into hot air. More commonly, slowly rotating agitators (or rakes) are used to facilitate fluidization in the feed zone where highly wet feed is fed into a continuous plug-flow dryer.

### 6.1.9 Centrifugal fluidized bed dryers

To intensify heat and mass transfer rates for rapid drying of surface-wet particles, a centrifuge-type device may be used so that the drag force due to the fluidizing gas can be balanced with an “artificial gravity” generated by rotating the bed on a vertical axis. The rotating fluidized bed equipment is complex and the decrease in drying times for most materials is normally not high enough or essential enough to justify the cost and complexity.

#### Table 5. Conventional versus innovative concepts in fluid bed drying

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Innovative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convective heat transfer</td>
<td>Convection + conduction (immersed heaters in bed)</td>
</tr>
<tr>
<td>Steady gas flow</td>
<td>Pulsed gas flow</td>
</tr>
<tr>
<td>Constant gas temperature</td>
<td>Variable gas temperature</td>
</tr>
<tr>
<td>Pneumatic fluidization</td>
<td>Mechanically assisted fluidization (Vibration/agitation)</td>
</tr>
<tr>
<td>Used for drying of particles</td>
<td>Drying pastes, slurries using inert media</td>
</tr>
<tr>
<td>Air/combustion has drying medium</td>
<td>Superheated steam for fluidization/drying</td>
</tr>
<tr>
<td>Air/drag resisted by gravity</td>
<td>Centrifugal beds (artificial gravity generated by rotation)</td>
</tr>
<tr>
<td>Single stage/multi-stage fluid beds</td>
<td>Multi-stage with different dryer types</td>
</tr>
<tr>
<td>Simultaneous fluidization of entire bed</td>
<td>Moving fluidization zone (pulsating fluidized bed)</td>
</tr>
</tbody>
</table>

### 6.1.10 Jet Spouted bed dryers (SBD)

Spouted bed dryers are found suitable for drying of particles, which are too coarse and dense to fluidize well without channeling. Unlike fluidized beds where the particle motion is random, movement of particles in spouted beds is a regular recirculatory motion. Both batch and continuous modes of operation are possible. Owing to their limited processing capability per unit floor area and high power consumption spouted beds have not found major commercial applications. The functioning of jet spouted bed dryer is shown in Fig. 3.

They are more commonly used for roasting (e.g., coffee/cocoa beans, soya beans). They have found limited applications for small scale drying of slurries and suspensions sprayed into a spouted bed of inert particles.
6.1.11 **Pulsed fluidized bed dryer**

In pulsed fluid bed dryer, fluidizing gas flows through a fraction of the grid surface area at a given moment and is then redirected to consecutive sections in fast succession (the gas plenum chamber is divided into several sections).

Notations given in Fig. 5 include dryer (1), rotating valve distributor (2), forced draft fan (3), induced draft fan (4), feeder (5), hopper (6), bag filter (7), electrical heater and gas burner (8) and control panel (9).

It has several advantages such as: easy fluidization for irregularly shaped particles, fluidization of particles with wide size distribution, and even fluidization of...
fragile particles are possible. Principle of the functioning of pulsed fluid bed dryer and a pilot scale pulsed fluid bed dryer are shown in Fig. 4 and Fig. 5 respectively.

6.2 Superheated steam drying in fluidized beds

Superheated steam drying (SSD) involves use of superheated steam in a direct (convective) dryer in place of hot air, combustion, or flue gases as the drying medium to supply heat for drying and to carry away the evaporated moisture. Dryer exhaust is steam, albeit at lower specific enthalpy. Superheated steam drying offers these advantages:

- No fire or explosion hazards
- No oxidative damage
- Ability to operate at vacuum or high pressure operating conditions
- Ease of recovery of latent heat supplied for evaporation as compared to conventional dryers with gas/air exhaust
- Higher drying rate possible for both constant and falling rate periods
- Better quality product under certain conditions
- Closed system operation to minimize air pollution

7.0 INTEGRATED BELT SPRAY DRYING SYSTEM (FILTERMAT DRYERS)

Many dairy products, foodstuffs and food ingredients are required in powder form and some of them are difficult to spray dry due to their carbohydrate, fat or protein contents.
Continuous powder production of this type of product in conventional one- or two-stage spray dyers is often associated with product quality deterioration, deposit losses and frequent cleaning procedures, and is therefore not acceptable. Successful drying of sticky, hygroscopic, thermoplastic and slowly crystallizing products into free-flowing agglomerated powders requires powder temperatures to be maintained at much lower levels than those possible in conventional spray dryer layouts. Completion of drying under these conditions also requires the powder to be held within the dryer for much longer times, too. A specially designed integrated belt spray dryer fulfills all these criteria. Its design combines a co-current nozzle tower dryer with a built-in conveyor belt. The transport time while powder moves with the belt is several minutes offering sufficient time to complete powder drying, agglomeration and cooling while maintaining the required powder temperature. For better understanding of the process, diagrammatical representation is given in Fig. 6.

7.1 Functioning of integrated belt spray dryer

The feed liquid or concentrate is pumped to a high-pressure nozzle assembly and sprayed downwards into drying air entering through a ceiling air disperser. The combined atomizer and air disperser operation creates in the main drying chamber an airflow pattern that directs the particles downwards onto the moving belt. The 1st drying stage is completed during this phase. Semi-dried particles accumulate on the belt as an agglomerated, porous powder layer. The drying air is exhausted through the powder layer and the belt, and thus drying continues during the time the powder is being conveyed. This completes the 2nd stage drying. Outlet air temperature control is important to obtain the moisture content necessary to achieve the exact degree of product agglomeration and porosity of the powder layer.

7.2 Important features of integrated belt spray dryer

- Ability to control temperature in drying/conditioning chamber
- Finest of particles are retained in the powder layer
- Negligible powder passes with the exhaust air to the cyclones
- Particle emission levels are very low even though bag filters are not used

8.0 TWO-STAGE HEAT PUMP SYSTEM COUPLED WITH FLUID BED DRYER

Heat pumps have been used to be energy efficient when used in conjunction with drying operations. Recent work at Norwegian University of Science and Technology has demonstrated the feasibility of fluidized bed heat pump dryer, which consumes less power as compared to conventional FBD. An idea of the functioning of this dryer is given is Fig. 7.

In this system, drying chamber (FBD) receives wet material and discharges dried product. This type of dryer can produce drying temperatures from -20°C to 60°C and air humidity from 20 to 90% (Chou and Chua, 2001).
9.0 AGGLOMERATION OF SPRAY DRIED FOODS

Agglomeration means getting smaller particles to adhere to each other to form a powder consisting of bigger conglomerates/agglomerates, which are essential for an easy reconstitution in water. One of the major objectives of new innovations in the area of spray and fluid bed drying is to produce instant powders by effecting agglomeration. The purpose of particle size enlargement by agglomeration is to improve certain physical properties of powders such as wettability, sinkability, dispersibility and solubility.

9.1 Type of agglomeration

For the production of stable agglomerates, the primary particles first have to be brought into contact with each other, which is usually achieved by an external force. In a second step, permanent adhesion forces must be established between these particles. Duration and intensity of these forces have an important influence upon agglomerate porosity, stability and agglomerate size (0.2-2 mm). The commonly used agglomeration processes can be divided into three groups:

- Pressure agglomeration (compacting)
- Growth (tumbling) agglomeration - dry and wet (rotating disc/fluid bed/steam jet agglomeration)
- Agglomeration by drying - caused by van der Walls forces/electrostatic forces

Mechanism of formation of agglomerates is explained in Fig. 8 given below for the sake of clarity.
Fig. 8 Mechanism of agglomeration

9.2 Spray agglomeration

During the spray drying process the aim is to produce particles with a big surface/mass ratio, i.e., small particles. The reconstitution in water of a powder consisting of small particles is however difficult and requires intensive mixing in order to disperse the powder, before it is totally dissolved. During spray drying agglomeration can be caused by one of these methods given below:

- Collision of particles from two or more atomization clouds, typically in a multinozzle unit, where the sprays from the individual nozzles are forced into each other
- Spray of concentrate/semi-dried particles onto a fluidized powder layer in an integrated fluid bed
- Spontaneous agglomeration by returning the fines into the dryer near the atomizing device, where they meet and collide with atomized wet droplets thus forming agglomerates consisting of many particles stuck together having a size of 100-500 microns

9.3 Steam jet agglomeration

Jet agglomeration is new process being used in food industry to produce agglomerates with instant properties from fine powders. Freely falling particles are
wetted by turbulent free jets of steam; colliding wetted particles form agglomerates, provide that their relative kinetic energy can be dissipated by the viscous liquid layers on the particles’ surfaces. The process is suitable for all foods that form sticky surfaces when wetted, and the short residence time and narrow residence time distribution allow the processing of material containing volatile components. Two different mechanisms contribute to the wetting process:

- Condensation of steam on cold particle surfaces and,
- Collision of particles with liquid droplets

While wetting by condensation is very effective, it occurs only as long as the particle’s temperature is below the equilibrium temperature corresponding to the prevailing RH in the drying chamber. Therefore lower the entry temperature, the faster the condensation on the particle surface.

10.0 CONCLUSION

There is a potential to improve existing technologies and to design intelligent combinations of current technologies that will lead to better quality products, smaller equipment size, greater reliability, safer operation, lower energy consumption, and reduced environmental impact while reducing the cost of drying. Further R&D is needed coupled with close interaction between industry and universities to enhance our understanding of the fundamental drying processes so that they may be applied to better design, optimize and operate the wide assortment of dryers in use today. Some of the areas, which need to be further explored, and towards which renewed focus could be expected are enumerated below:

- Newer atomization techniques
- Atomization of viscous/non-Newtonian slurries
- Interaction of sprays with gas-particle flow in spray chamber causing agglomeration
- Novel spray chamber designs
- Steam drying in spray/fluid bed chambers
- Spray drying at reduced pressures in hot air/superheated steam
- Enhancement of shelf life of indigenous dairy products using spray bed drying

11.0 REFERENCES


1.0 INTRODUCTION

Microwave heating and drying processes have been well established in various industrial applications and in many cases are replacing the less efficient and conventional methods. However, these processes are not fully understood which is limiting the optimization procedure, particularly with regard to uniformity of moisture and temperature distribution in the treated material.

In order to investigate this problem, it is necessary to identify the various parameters (thermal, electro magnetic) involved in the microwave heating process and to show the interaction between these parameters during the process. Thus in order to effectively utilize microwave energy the entire bulk of material should be penetrated which requires a relatively low frequency. However, the power absorbed into the body will decrease with decreasing frequency. Hence to maintain the same heating rate at lower frequencies, it would be necessary to increase the field intensity up to the limit of arcing.

The apparent limitations of the microwave process are established by the material quality, processing time, temperature and moisture distributions. In other words the process rate depends on the maximum permissible temperature and/or moisture gradients.

2.0 ENERGY CONVERSION PROCESS

The conversion of electro magnetic energy into heat in a lossy dielectric body is understood better first by considering the Poynting Vector distribution in terms of the dielectric properties of heterogeneous materials. The mechanisms of heat and moisture transfer into and out of the body are investigated as a function of time and position. The process of microwave heating consists of dissipating part of the microwave energy flow in a heated material, which, in general, is a lossy dielectric. Dielectric losses can be formally described by considering the dielectric constant to be a complex number in the form:

$$\varepsilon = \varepsilon_0 \varepsilon' (1 - J \tan \delta)$$

According to the Poynting theorem, the complex Poynting vector representing the total energy few through a certain surface S is given for time harmonic fields and non magnetic materials by:
where, $R_e \int_S n \, da = \text{total power dissipated}$

$I_m \int_S n \, da = 2\pi x \text{difference of the values of magnetic and electrical power stored}$

The power dissipated in the heated body,

$$P_{\text{diss.}} = R \int_S n \, da = \frac{1}{2} \int \sigma E^2 \, dv + \text{Polarizationlosses} = 27.8 \times 10^{-12} f \int \epsilon \| E \|^2 \, dv$$

Where $P_{\text{diss}}$ is in watts, $f$ frequency in hertz, $E$ electric field intensity (Peak Value) in volts/meter.

During the microwave heating process, energy conversion takes place throughout a heated body and the temperature rise at any point of the body is related to the power dissipated and absorbed by:

$$\frac{\partial T}{\partial t} = 0.239 P_{\text{diss.}} / C \rho ^{0} C/\text{sec}$$

where $P_{\text{diss.}}$ is power dissipated and absorbed at particular point in watts, $C$ is the specific heat of the material in calories/gram, and $\rho$ is the density of the material in gram/cm$^3$. For a heated body, exposed to a plane electromagnetic wave at normal incidence, the incident power is partly reflected, so that

$$P_{\text{ref.}} = (\Gamma)^2 P_{\text{inc.}}$$

where $\Gamma$ is the reflection coefficient of the material surface which for a plane wave, is related to the material permittivity by the relation

$$\Gamma = \frac{Z_{\epsilon} - Z_0}{Z_{\epsilon} + Z_0}$$

where $Z_{\epsilon}$ and $Z_0$ are intrinsic wave impedances of the material and free space. The remaining past of the incident power is dissipated and absorbed in the body.

Some times it is convenient to use a parameter called power penetration depth $D$, which is defined as the distance from the surface at which the transmitted power drops to 36.8% of its value at the surface. It means in a layer of thickness $D$,
63.2% of the incident power is absorbed. For layers of thickness 2D and 4D these
valves are 86.5% and 98.2% respectively. The penetration depth D is related to the
material permittivity. For most practical cases, the power penetration depth is only a
fraction of the wave length.

3.0 PROPERTIES OF HEATED MATERIALS

It is clear from the energy conversion process, that dielectric properties of
heated materials play a fundamental role in the microwave heating process. Most of
the materials heated by microwave energy are heterogeneous mixtures and contain
water. Water in heterogeneous systems appears in different forms, i.e. as free water,
bound water or water of crystallization, various relations have been developed for
describing the macroscopic dielectric behaviour of a mixture consisting of a granular
material with permittivity \( E_1 \), dispersed in an another substance with permittivity \( E_\phi \).
The immediate surrounding of considered granule is described by an effective
"internal" permittivity \( E^* \), in which all interactions of the other granules are accounted
for.

The permittivity of powdered milk and whey was measured with respect to
moisture content, temperature and density, for the possible use of these data for the
application of microwave content on line during processing. Since these materials
have constant chemical composition, the parameters which affect the permittivity are
moisture content, density and temperature.

4.0 HEAT TRANSFER PHENOMENA

As a result of the dissipation of microwave power, the temperature of the
heated body rises to a value given by

\[
\frac{dT}{dt} = 0.239 \frac{P_{\text{diss}}}{C \rho} \text{ °C/Su.}
\]

The initial temperature distribution of the absorbed power which is non-uniform creates heat
transfer from the surface into the body as well as from the surface to the
surrounding. So, it becomes important to investigate the mechanisms of heat
transfer in the heated body in order to find the temperature distribution at different
moments of the heating process.

Heat transfer is defined as the transmission of energy from one region to
another as a result of temperature difference between them, and according to the
second law of thermodynamics, from the region of higher temperature to the region
of lower temperature. There are three distinct modes of heat transfer: Conduction,
radiation and convection, but in microwave drying process, these mechanisms act
simultaneously.

During the conduction heat flow, the energy is transmitted by direct molecular
communication without appreciable displacement of the molecules. The rate of heat
flow is governed by Fourier’s Law

\[
Q_k = -KA \frac{dT}{dx}
\]

where K is the thermal conductivity of the material, A is the area through which heat
flows and \( dT/dx \) is the temperature gradient. Radiation heat flow is a form of an
electro magnetic wave radiated from the body of higher temperature to the body of lower temperature. The rate of heat flow is described by Stefan-Boltzman’s equation

\[ Q_r = \sigma \varepsilon AT^4 \]

where is the Stefan-Boltzman constant, \( \varepsilon \) is the emissivity of the surface, Active surface area and \( T \) is the temperature. In the convection process, heat flows by combined action of heat conduction, energy storage and mixing motion. The rate of heat flow can be derived from Newton’s equation;

\[ \dot{q}_c = h_c A \Delta T \]

where \( h_c \) is the average unit thermal convective conductance, \( \Delta T \) is the temperature difference.

The warm up period in a microwave process, sets up a temperature distribution, which undergoes change with time at various points of the system. That is why the transient flow problems are more complex than those of steady state and can be solved only by approximate methods. When a plane electro magnetic wave illuminates, the distribution of the absorbed power follows the exponential law. This remains constant as long as the dielectric properties of the body are constant. Exponential distribution of heat sources in the system produces transient heat flow by conduction into the heated body, which is a wanted effect, and an outflow of heat from the surface to the surrounding atmosphere by convection and radiation, which is a loss.

To find the temperature distribution in a heated body, it is necessary to solve general heat conduction equation:

\[
\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2} + \frac{\delta^2 T}{\delta z^2} + \frac{q}{k} = \frac{1}{a} \frac{\delta T}{\delta t}
\]

where \( a = K/C \rho \), called thermal diffusivity and \( q \) is the heat generated per unit volume. For one dimensional heat flow in a lossy half space, this equation reduces to

\[
\frac{\delta^2 T}{\delta x^2} + \frac{q(x)}{K} = \frac{1}{a} \frac{\delta T}{\delta t}
\]

which should be solved in the presence of heat losses from the surface (boundary conditions) and taking the exponential distribution of heat sources into account. (Initial Conditions).

A simplified version of the solution of Source Free Heat Diffusion Equation:

\[
\lambda^2 T = \frac{1}{a} \frac{\delta T}{\delta t}
\]

where \( a \) is diffusion constant and the temperature \( T \) is a function of position \( r \) and time \( t \). Taking the three-dimensional Fourier transform in \( K \)-plane leads to;
\[-K^2 = -\frac{1}{a}\frac{\Delta \Phi}{\Delta t}\]

hence the transform of the solution is given by

\[\Phi = A(K)e^{-k^2at}\]

where \( A(K) \) is the Fourier transform of \( T \) at \( t = 0 \) i.e. \( T(\vec{r}, 0) \)

Taking the inverse Fourier transform of \( \Phi \) leads to the solution.

4.0 MICROWAVE PROCESSING: APPLICATION AND SCOPE IN DAIRY AND FOOD INDUSTRY

The acceptance of microwave processes as standard unit operations by the food industry has been impeded by the “black-box” approach of many equipment manufacturers and food processors in process development. This is seen as inappropriate to future development of microwave food processes. The ability to predict time-temperature profiles in high moisture foods based on fundamental properties of biological materials would facilitate the development and design of industrial microwave food processes. An unsteady state, two dimensional microwave freeze-drying model has been developed, a distinct improvement over flat slab models.

5.0 REFERENCES


1.0 INTRODUCTION

There are several basic drying methods available for food dehydration to provide extended shelf-life and to permit economics in packaging and transportation. The method of choice very much depends upon the type of food to be dried, the quality level that must be achieved, and the cost that can be justified. The quality of dehydrated food product is judged by the amount of physical and bio-chemical degradation occurring during the drying process.

In recent years, freeze drying has been developed to a highly advanced state. Much of the development work has been aimed at optimizing the process and equipments to reduce drying costs. Freeze drying can be used to dehydrate sensitive high value liquid foods and it is the only method to preserve delicate flavours, colours, size, shape and textural attributes of the original food product. An attempt has been made in this lecture note to briefly describe the concept and developments taken place in freeze drying operations.

2.0 FREEZE DRYING

Freeze drying is performed in freeze drying equipment which consists of drying chamber with temperature controlled shelves, a condenser to trap water removed from the product, a cooling system to supply refrigerant to the shelves and condenser, and a vacuum system to reduce the pressure in the chamber to facilitate the drying process.

In freeze drying, the food product is frozen, then the water is removed by sublimation and desorption under vacuum. The sublimed ice is pulled from the vacuum chamber by vacuum pumps or steam jet ejectors. The heat of sublimation is supplied by conduction or radiation. Frozen water sublimes at temperature of 0°C or lower under pressures of 627 Pa or less.

Freeze drying produces the highest quality food product. This is largely because the structure of the food is not severely damaged as in other drying processes. When water is removed from a material by sublimation, a porous, non-shrunken structure remains. Freeze-dried foods are easily rehydrated. Little or no loss of flavour and aroma occur during freeze drying. Product quality remains high because the low drying temperature is not conducive to most degradative processes, such as non-enzymatic browning, protein deterioration, and enzymatic reactions. The greatest disadvantage of freeze drying is the cost. The drying rate is slow and
the use of vacuum adds to the cost. The final product has a low moisture content, so some cost is saved by alleviating the refrigeration and storage costs.

3.0 PROCESS

Freeze drying is performed at −10°C to ensure that the water remains in a frozen state. An absolute pressure of 2 mm or less is common. The heat of sublimation must be controlled to ensure that the ice sublimes without melting. Sublimation take place from the surface of the ice, and as it continues, the ice front recedes towards the center of the food piece, that is, the food dries from the surface to inward. Finally, the last of the ice sublimes and the food is below 5% moisture. Since the frozen food remains rigid during sublimation, escaping water molecules leave voids behind them, resulting in a porous sponge like dried structure. The drying rate is influenced by the thickness of the product and its composition. The thinner the product, the higher the drying rate. Optimum rates are achieved at thickness of ½ to ¾ inch. Foods with higher sugar contents have slower drying rates.

Freeze drying operation has three steps: the freezing of the product, ice sublimation, and water vapour removal. The removal of water vapour from the chamber is the most expensive of those processes, and the feasibility of freeze drying often hinges on this step. A vapour trap is placed between the drying chamber and the vacuum pump or steam jet ejectors. The vapour trap has refrigerated surfaces and the vapours condense on the trap as they contact it. The efficiency of the vapour trap is dependent on the pressure difference between the freeze drying chamber and the vapour trap area, the temperature of the trap, the thickness of ice built up on it, and the temperature difference between trap surface and the evaporating refrigerant. The less efficient the vapour trap, the lower the temperature in the freeze drying chamber. The area of the vapour condenser is usually equal to the shelf area. Water is removed by the vacuum pump, and the vacuum pump also serves to maintain sub-atmospheric pressures in the drying chamber. The removal of non-condensable gases reduces the resistance of the sublimed water vapour migrating to the condenser. The presence of non-condensables in the drying chamber greatly reduces the efficiency of the dryer.

4.0 PILOT SCALE FREEZE DRYERS

Portable freeze dryers are used in the food industry in laboratories and in instances when very small amounts of product are required. These units are usually mobile and have self contained refrigeration, heating and vacuum pumping processes. Typical capacities range from 2 to 20 kg of frozen product or 6 to 36 sq. ft.

The factors that influence the sizing of a freeze dryer are chamber size, capacity of vacuum pump and condenser and plate area. A 1:1 scale-up ratio is used. Scale up is accomplished by increasing the drying surface area, to compensate for the increased food capacity. The vacuum pump and condenser area are scaled up proportionally with the increase in drying area. The thickness of the product is not typically increased above the optimum drying thickness found in pilot scale tests.
5.0 INDUSTRIAL FREEZE DRYERS

5.1 Tray freeze dryer

The most common type of freeze dryer in operation is the tray freeze dryer. The condensers are mounted in the same chamber as the tray-heater assembly or in a separate chamber joined by a wide tube. The size of these dryers range from 120 to 220 sq ft and the product rests on trays within the drying chamber. If the required capacity of the dryer is great enough, several freeze dryers may be operated from a central tray heater, condenser, refrigeration, and vacuum pump system. The system would be programmed to stagger the dryer cycles and even out the load on each part of the system. Each dryer would be individually controlled by its own panel, yet the operation would be semi continuous.

5.2 Tunnel Freeze Dryer

This process consists of tray being loaded into the freeze dryer at one end and dried product being discharged from the other end. The process takes place in a large vacuum cabinet, and the trays are loaded and unloaded through vapour locks. The dryer is divided into five independent processing areas. It is cooled by an aqua-ammonia absorption refrigerator which can control the load more readily. This type of freeze dryer is advantageous because the flow rate can be increased as demand increases, although it is difficult to switch from one product to another.

6.0 ACCELERATED FREEZE DRYING PROCESS

In conventional freeze dryers, as drying progresses and the ice front recedes, drying rate drops off. The porous dried layer ahead of the receding ice layer acts as an effective insulator against further heat transfer. The porous layer slows down the rate of escape of water molecules subliming from the ice surface. In the modern, well-engineered freeze drying systems, some of the more practical means of increasing overall drying rates have been introduced. They make use of energy sources with penetrating power, such as infrared and microwave radiations, to pass through dried food layers into the receding ice core.

Infrared radiation drying is often used in conjunction with freeze drying to accelerate the sublimation process. The infrared radiation is generated by electrical methods including incandescent lamp (100 to 5000 W), quartz tubes, and resistance elements. The heat radiation is projected from planes arranged above the trays of product. Band systems are common because of the need for the product layers to be no thicker than 3 mm. Slurries and gels work best in this system, providing optimal penetration. This drying technique produces high drying rate without burning.

The ability of microwave energy to selectively heat ice crystals in matter makes it attractive for accelerating the final stages of freeze drying. High-frequency radio waves of up to 30,000 MHz are utilized in microwave drying. As energy enters the foods, the molecules try to align in the electric field orientation. They oscillate around their axis, generating heat within the food, resulting in dehydration. The waves bounce from wall to wall, until eventually all of the energy is absorbed by the product. In this manner, the drying rate is increased greatly. This type of heating is
highly efficient, and power utilization efficiencies are generally greater than 70 per cent. Important commercial aspects include the ability to maintain colour and quality of the natural food.

Freeze drying process can also be accelerated by converting the liquid foods to foams before drying. Foams dry more rapidly than liquids, allowing the use of lower temperatures and shorter residence times. Gases are dissolved in the liquid feed under considerable pressure to produce foams. The foaming of liquid is due to surfactants that are either naturally occurring or added.

In spite of developments in the freeze drying operations, the cost of drying is still in the order of 2 to 4 times greater per weight of water removed than other common drying methods. It is well known that in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment. Therefore, it is worth considering the freeze concentration equipment to concentrate the liquid food products up to 30 to 35 per cent total solids level prior to the final drying in industrial freeze driers. With the development of improved wash columns as well as multi-effect freeze concentration systems, freeze concentration is emerging as a low energy intensive process. This would not only reduce the cost of freeze drying but also enhance the through put of the freeze dryers.

7.0 DEVELOPMENT IN FREEZE DRYING EQUIPMENTS

Food companies wishing to install freeze drying equipment on a major scale must consider the process from an overall systems approach. This will include material handling, the freezing operation, loading of drier trays, the drying operation, high vacuum and condenser requirements, unloading of trays, packaging requirements, and of course equipment, labour and utility costs. Many equipment companies have designed total system which can be custom engineered for a specific product and the needs of the manufacturer. It is common for such equipment companies, working with the food manufacturer, to design and install the entire freeze drying plants.

In a typical microprocessor based freeze dryer, automatic start up feature ensures the correct sequential start up of refrigeration and vacuum systems at the touch of a button, eliminating the potential for user error. The vacuum brake system maintains system vacuum pressure and prevents oil from back streaming into the system in the event of a power failure or improper shut-down procedure. Electric purge system isolates the vacuum pump from the vacuum system so that volatile vapours may be purged from the pump oil thereby extending the life of the pump. Latest freeze drying equipments are available with CFC-free refrigerants and with a wide selection of temperature ranges. An extremely efficient silicone heat transfer system provides uniform temperatures from –70°C to +65°C coupled with easily achievable shelf temperature control of +/-1°C, enabling a wide variety of applications. Manufactures are offering product chambers with shelf configurations and areas to suit the requirements of product nature and plant capacity, incorporating pneumatically controller auto-locking insulated doors.
8.0 CONCLUSION

Freeze drying can be used as the best alternative for preservation of value added dairy and food products, where nutritional, organoleptic and rehydration properties are of prime concern. Lot of scope exists for freeze drying of indigenous dairy products like Paneer, Basundi and Kulfi mix for export purposes. The advent of continuous and specific dryers for different food products coupled with accelerated sublimation methods reduced the operating costs of freeze drying. Developments in the freeze concentration systems paved the way for freeze drying of liquid food products like fruit juices on commercial scale.

9.0 REFERENCES

1.0 INTRODUCTION

Retorting or canning may be defined as a process for preserving food achieved by the application of a thermal sterilization procedure to products packed in hermetically sealed containers. The contents of can are generally ideal growth media for a vast array of microorganisms. In particular, and in contrast to other prepared food products for retail sale, they will readily support the growth of anaerobic over aerobic organisms. Since the most familiar signs of food spoilage reflect the growth of aerobes, this could lead to contaminated can contents becoming toxic before becoming noticeably spoilt.

Canning, therefore, is a technology where mistakes cost lives - a fortunately rare situation in the world of food processing. Although an increasing quantity of food is sterilized prior to being packaged aseptically, the majority of food is still packaged in either metal cans or flexible pouches and then sterilized. It is this aspect, which is being discussed in this paper in greater detail. Fundamental aspects such as principles of thermal processing including microbiological considerations have been covered including commercial methods of sterilization.

2.0 OUTLINES OF CANNING/RETORTING OPERATIONS

Basic operations connected with the conventional canning / retorting process include; preparation of the food, filling of the container, exhausting, sealing of container, thermal processing/sterilization, & cooling of the cans and its contents. All these aspects except thermal processing are described only briefly in this paper.

2.1 Preparation of the food

A variety of processes such as grading, trimming, washing, blending, blanching, pre-cooking etc. are employed. The pre-canning operations should be carried out effectively but rapidly since undue delay at this stage will permit the development of rapidly growing microorganisms which may render the heat process inadequate.

2.2 Filling

The filling of containers, which is accomplished mechanically or by hand, requires to be carefully controlled. This applies not only to the gross weight of
material filled, but where the product is non-uniform, as in the particulate products, to the amount of each phase filled. Correct and accurate filling is important from the economic standpoint as well as prevention of occlusion of large volumes of air inside the can, which might decrease the severity of heat treatment. Fig. 1 shows the loading operation of trays over a trolley into the retort for processing.

![Loading of trays containing food material in retort](image)

**Fig. 1** Loading of trays containing food material in retort

### 2.3 Exhausting

An essential operation in the canning process is the removal of air from the container before it is closed. This is necessary for several reasons such as minimization of strain on the can seams or pouch seals through expansion of air during heat processing, removal of oxygen, which accelerates the internal corrosion of the container and creation of a vacuum when the container is cooled. Additional advantages which result from exhausting include prevention of oxidation and preservation of vitamin C content. In commercial practice the procedures adopted for the removal of air from the cans and flexible pouches include heat-exhaust in which can contents are heated immediately before sealing, mechanical exhaust in which air is removed mechanically and steam injection which involves injecting a blast of steam into the headspace as the lid of the can is being positioned for sealing.

### 2.4 Sealing of the container

Metal cans, glass bottles and flexible retortable pouches are commonly used in modern day retorts. Can closing machines operate at very high speeds. The sealing of flexible pouches relies upon the fusion of two thermoplastic materials through application of heat by means of heated pressure plates or jaws. The inner
ply or fusion material is generally either polypropylene or a modified high-density polyethylene.

2.5 Thermal processing/sterilization

After exhausting and closing, the containers must be heated for an accurately predetermined time and temperature in an atmosphere of saturated steam, in heated water, or in an air-steam mixture. The sterilizing action of steam depends largely upon the transfer of its latent heat of vaporization to the surface of the cans on which it condenses. Dry or superheated steam condenses less readily and is therefore less efficient than saturated steam in transferring heat. The complete elimination of air from the retort is a vitally important factor in thermal processing and, unless special provision is made to maintain a uniform steam-air mixture, serious under processing may result. Retorts should be so constructed that removal of air is facilitated. This is brought by a procedure known as 'venting', the purpose of which is to displace all air in the retort by steam before it is brought to operating temperature.

When foods are preserved by heat, the heating process serves to reduce the concentration of microorganisms in the food. It may also inactivate enzymes present. It is not a necessary requirement of the heating operation that it should eliminate all viable organisms from the food. What is required is that the resulting product should be both acceptable to the consumer and safe to eat at the end of a predetermined storage period under defined conditions.

pH of the food strongly influences the nature of the heat process required to produce an acceptable product. Preserved foods range in pH from neutrality to about pH 3.0. The inhibiting effect of acids on spoilage organisms starts to become apparent at pH 5.3, while Clostridium botulinum and other food-poisoning organisms are inhibited at pH 4.5. The important demarcation point occurs at pH 4.5. For low-acid foods (pH > 4.5), the requirement to destroy food-poisoning organisms such as Clostridium botulinum leads to the use of the severest class of heat processing, a treatment above 100°C. Such processes should be designated as 'commercial sterilization', which may be defined as heat processing designed to inactivate substantially all micro-organisms and spores which, if present, would be capable of growing in the food under defined storage conditions.

Apart from pH thermal conditions needed to produce commercial sterility depend on several factors such as storage conditions of the food following the thermal process, heat resistance of the micro-organisms or spores, heat transfer characteristics of the food, its container and the heating medium and the initial load of micro-organisms.

2.5.1 Thermal destruction of spoilage microorganisms

The microbiological stability and eating quality of heat-processed foods are affected both by the temperature and duration of the thermal process. Under-processed food will be liable to bacterial spoilage, and over-processed food will be nutritionally and organoleptically inferior. The parameters of a suitable thermal process may be estimated on the basis of assumptions regarding the heat resistance of the spoilage microorganisms, the kinetics of quality loss and knowledge of the temperature history of the food during processing.
It is customary to assume that bacterial spores (as also vegetative cells) have a logarithmic order of death, i.e. when a given spore preparation is held at a constant temperature sufficiently high for thermal destruction to occur, the number of spores per unit volume decreases as shown in Figure 2.

![Image: Relationship between spore concentration and time of heating at a constant temperature]

**Fig. 2 Relationship between spore concentration and time of heating at a constant temperature**

Clearly, from Figure 1, if the spore concentration is \( N_1 \) spores/ml of suspension at time \( t = 0 \) and \( N \) spores / ml at time \( t = t \) then;

\[
\log \frac{N}{N_1} = -\frac{t}{D}
\]

where 'D' is a constant known as the 'Decimal Reduction Time' and is the time over which the spore is reduced tenfold (\( \log 10 = 1 \)). For the purpose of heat process calculations the decimal reduction time is assumed to be independent of the initial spore concentration but a function of temperature. It is also dependent not only on the strain of the species of bacterial spore and the medium in which the spores are heated, but also on the previous history of spores. An immediate result of equation 1 is that since \( N \) can become equal to zero only when \( t \) becomes infinite, it would appear to be impossible to sterilize a spore concentration with absolute certainty. From this the concept of 'commercial sterility ' has arisen. D value for *Bacillus stearothermophilus* is taken as 5 min. whereas for *C. botulinum* it is 0.25 min.

### 2.5.2 Concept of \( F_0 \) value and measurement of process lethality

Taking \( D=5 \) for *B. stearothermophilus* and the initial number of spores to be \( N_0=10,000 \), if it was required to reduce this number to 1 in the heat process, then it is clear that 4 decimal reductions would be needed. The time at 121.1°C required to accomplish this would be \( 4 \times D \) i.e. \( 4 \times 5 = 20 \) min. Similarly, if the spores were of *C. botulinum* the required time would be \( 4 \times 0.25 = 1 \) min at 121.1°C. Putting this in
mathematical terms $N_0 = 10,000$ and $N_t = 1$. The number of decimal reductions required is given by;

$$\log \frac{N_0}{N_t} = \log N_0 - \log N_t = (4 - 0) = 4$$

This $\log N_0 / N_t$ is sometimes referred to as the 'order of process' factor 'm', and the value of the product of $m$ and $D$ is called the 'process value' or more commonly 'F value' i.e.

$$F_0 = mD_0 \quad (2)$$

Obviously a process designed to reduce the spore population to 1 is inadequate. What, then, would be regarded as a commercially safe heat process? Commercial sterility is therefore taken as a compromise whereby initial bacterial load is taken through sufficient decimal reductions to reduce the possibility of a single organism surviving to an acceptably low level. What constitutes the acceptably low level depends upon the organism the process is designed to destroy.

*Clostridium botulinum* is usually taken as the organism whose destruction is the process objective because, during its growth, which is particularly favoured by the low oxygen conditions inside an hermetically sealed container, it releases a substance that is extremely toxic. An 'acceptably low level' in the context of this pathogenic organism means less than one in a billion (i.e. $10^{-12}$) chance of survival. Thus, if there were one organism in the container initially,

$$m = \log \frac{N_0}{N_t} = \left( \log 1 - \log 10^{-12} \right) = 12 \quad (3)$$

$$F_0 = mD_0 = 12 \times 0.25 = 3 \quad (4)$$

Since, in this case, the reference organism is *Clostridium botulinum*, and the reference temperature is 121.1°C, this is more correctly written as;

$$F_{C. botulinum}^{121.1°C} = 3 \quad (5)$$

which is usually shortened to $F_0 = 3$. $F_0$ values commonly used by canners for medium- and low-acid products range from 6 to 14 to give an additional safety margin to compensate for temperature-measurement inaccuracies.

By taking a series of readings over the length of the process, the temperature history of the cold spot in a can will be revealed. It is necessary to relate this temperature history to the destruction of a selected microorganism. Hence the $D$ value for an organism at different temperatures must be known. The graph of the $D$ value plotted on a logarithmic scale against temperature on a normal arithmetic scale is approximately linear over the range of temperatures used in conventional retort processing. The temperature interval over which the graph passes through 1 log
cycle is called the ‘z’ value. Different strains of *C. botulinum* have different z values but usually a value of 10 is taken for process calculations.

For the purpose of heat-process determination with respect to their lethality towards specific microorganisms, the reciprocal of the D value, called the lethal rate (L) is used. F value is then taken as the total integral lethal rate and is given by the equation:

\[ F = \int_0^t L \, dt \quad \text{and} \quad L = \frac{1}{\log^{-1} \left( \frac{121.1 - CT}{z} \right)} \]

where CT is the temperature of the cold spot (usually centre of the can) in the container.

2.5.3 Practical applications of process lethality measurement

The theoretical aspects described above relate to a spore suspension in which the temperature varies with time but not location. Nevertheless for food in containers such as cans, heated and cooled by external agencies, the temperature in the food during the process varies from point to point. In this situation the probability of spore survival should be integrated over the contents of the can. However, such a procedure is possible only if the temperature history of every particle of food in the can will be inferred. A common practice is to assume that the can is a homogeneous right-circular cylinder of material heating and cooling purely by conduction. This is to ignore the enormous variety of heating regimes that occur in real packs of canned foods. There is likely to be at least a limited convective product movement, which may change as heating progresses due to the reduction of density gradients and/or gelatinization of the contents of the can. Packs will be non-homogeneous (fluid-solid mixtures, often non-uniform throughout due to settlement of the contents). The headspace gases will locally reduce heat transfer to the contents, and so on. All these considerations do not lead to a simpler method of calculating process lethality.

An alternative simple approach is to base calculations on a single temperature history determined at the slowest heating point within the can. In the case of pure conduction heating and cooling, the F value calculated for temperature histories measured at locations in the vicinity of this point will probably show relatively little spatial variation. Towards the outside of the can, F values increase considerably. Thus, it is reasonable to assume that if the material at the slowest heating point is adequately processed, overall the material has, on an average, received a more severe and, therefore, safer process. For cans where free convection prevails, temperatures are more uniform throughout and the question of product location is of less relevance.

If it is desired to establish a satisfactory thermal process for a new product, a decision is first made as to the probable value of F₀ required to achieve commercial sterility. Next, a process has to designed to achieve this F₀ value. A specific F₀
value can be achieved by any number of temperature / time combinations. The availability of equipment will place some constraints on the process adopted, but a major consideration should be the nutritional and sensory quality of the finished product brought about by chemical activity during the heating process. While process value (F value) relates to the effect of exposure time at a specific temperature on a specific organism, changes with respect to nutritional and sensory quality are better described by cook value (C_g value).

To assess the F_0 value achieved in any specific set of processing conditions, temperature history measurements at the thermal center of test cans are required. Experimental determinations of temperature histories are most conveniently made with thermoelectric thermometers. Several thermocouples specifically designed for this purpose are available commercially. Where cans/pouches are agitated in a rotary retort, consideration must be given to the possibility that the stirring effect of the thermocouple probe appreciably enhances heat transfer in the test can.

Once a process has been developed by these techniques, it should be further validated by a carefully planned programme of incubation testing of canned product produced first in pilot scale and, subsequently, in production runs. After this validation, routine testing should be instituted to give assurance that the required F_0 value is maintained in subsequent production.

2.5.4 Commercial sterilization systems

Retorts using steam, hot water or air-steam mixture for sterilization of food products in cans, glass bottles and flexible pouches most commonly used in food processing industries are of several types such as; batch wise retorts-without agitation, rotating retorts, continuous process retorts, hydrostatic retorts, direct flame sterilization and flash "18" process based retorts. Main features of these retorts are briefly described below.

2.5.4.1 Batchwise retorts - without agitation

Functional aspects of a batch vertical/horizontal retort are shown in Fig. 3. It consists of cylindrical pressure tank, into which the cans containing the food product, placed in cages are then lowered. Steam flows into the retort from the top and air is sucked out at the bottom. After heating, cooled water is sprayed into the retort. To prevent the pressure in the cans from becoming higher than that in the retort itself, compressed air is blown into the retort to compensate for the pressure drop, and when the temperature is reduced to below 100°C, the retort may be opened. Relative ease to maintain at a constant temperature, flexibility with regard to package type and low cost are some of its advantages whereas poor heat transfer due to no mixing and high labour input are some of its disadvantages.

The production of retort processed foods in pilot plant scale has been found to be associated with the less problems as the processing operations are simple and processing fault can be easily overcome. When the process is up-scaled, the problems associated in the operation are numerous and need systematic approach to overcome them.
2.5.4.2 Rotating retorts

In stationary sterilization, when dealing with liquid and semi-liquid products, the heat mainly enters the container by way of heat transfer known as convection. If there are solid parts in the food, the rate of heating is slowed down. Many semi-liquid products are heated by convection and conduction simultaneously. The process is longer because of the slower heat transfer to the coldest point of the contents in the can. It is clear that a method of movement, which brings about a quicker rise in temperature of the contents to the temperature of the retort, has many advantages such as:

- Higher temperatures can be used with precise control of the sterilization time, without burning or overcooking high viscosity semi-liquid or heat-sensitive food products
- Many products with a liquid component only can also be improved by the quicker rise in temperature of the contents
- Sterilization with a shorter time at high temperatures improves the colour, taste, flavour, consistency and nutritive value of many preserved products
- A further range of sterilization times and temperatures can be available for various products in various can sizes, and it is possible to obtain various sterilization processes, with the same sterilization effect ($F_0$ value) and the desired degree of cooking ($C_g$ value).
- Substantial avoiding of fat and jelly deposition
- Better maintenance of the structure and consistency
- Longer storage time due to less heat damage
- Cooling with sterilized water, no contamination possible
- Overpressure independent from temperature
- Safety in case of power cut

A rotary retort is shown along with its process control features in Fig. 4 given below:
Fig. 4 Rotary sterilization with process controls and overhead tank

The optimum sterilization properties of the rotary retort ensured growing sales in the meat, vegetable, fish and milk processing industries so that today about 400 manufacturers in 48 countries throughout the world use rotary sterilization for their products.

2.5.4.3 Continuous process retorts

They are often called 'continuous cooker-coolers' and are used in large industries. Generally there are three sections in a continuous process retort where in the 1st section cans are heated, in the 2nd section cans are cooled under high pressure, and in the third section they are cooled at atmospheric pressure. The cans are transported in a helix positioned on the periphery of a barrel, and when they have been transported one revolution of the barrel they have at the same time been moved one step along the retort. Simultaneously, the can rotates around its own axis. The effect of this is a flow pattern in the package enhancing heat transport in liquids. There is high pressure in the retort to prevent differences in pressure in the
can and retort. The disadvantage with these retorts is the limitation on the size of the cans, as they are built for one can size.

2.5.4.4 Hydrostatic retorts

A hydrostatic retort consists of a chamber equipped with steam injection. The chamber is connected to two water columns (barometric leg), which are used to adjust the pressure in the chamber. If the height of the water columns is changed the steam pressure is changed and thus the maximum temperature obtainable is also changed. These retorts are often very tall. To get a temperature of 116°C, a difference in height between the two water columns of 10.7 m is needed, whereas for 121°C it is 13.7 m. A conveyer, which may be altered to accommodate different can sizes, travels through the steam chamber carrying the packages. The sterilization time may be changed by varying the speed of the conveyer. The flexibility and capacity are the major advantages of this type of retort. The disadvantages are the size of the equipment and high capital costs.
2.5.4.5  Direct flame sterilization

Equipment for sterilization of cans transported through direct flames has been developed and is commercially available. The air temperature in contact with the cans is in the region of 1200-1400°C. The speed of rotation of the cans is high in order to avoid superheating of the can itself and thus the product.

![Figure 6: Direct flame sterilizer](image)

2.5.4.6  Flash "18" process

The flash ‘18’ process is unique in that the product is brought to sterilizing temperature prior to filling through steam injection heating, and then pumped while at sterilizing temperature to a "hot fill" operation carried out under pressure to accomplish sterility at the product-can wall interface.

![Figure 7: A diagrammatic representation of Flash 18 process of sterilization of foods](image)

Conventional filling equipment and steam-flow can sealers are housed in a pressurized room or "tank" maintained at 18 lb of air pressure. Hot product enters
the tank at a sterilization temperature of 130°C. It then flash cools to 124°C (the boiling point at 18 lb of air pressure). The filled and sealed cans are the processed through a continuous horizontal retort to accomplish a controlled hold time at 124°C to sterilize the inside can surfaces and deliver the required process time before final cooling and release to the outside through pressure seal cans. This system is used primarily for large institutional size cans that would otherwise require such long retort processes that the resulting product quality would be unacceptable.

2.6 Cooling of cans and its contents

After the cold spot has received a heat treatment adequate for commercial sterilization, it is desirable to cool the product as rapidly as possible to avoid deterioration in food quality. Additionally, a long, slow cooling process can lead to thermophilic spores germinating and multiplying to cause spoilage. The water used to cool the processed containers must be chlorinated because, while the containers are hot, the sealing compound may be molten so that there is a slight possibility that a drop of cooling water could be pulled through the seam by the vacuum forming in the headspace. Although this undesirable occurrence is only a remote chance (usually 1 in $10^5$), leaker spoilage is, by far, the most common microbiologically based reason for rejection of canned foods.

3.0 ADVANCES IN MEASUREMENT OF PROCESS LETHALITY

Heat penetration measurements, product formulation, container specification, filling and closing conditions etc. are the basis of each thermal process design. Modern data logging devices automatically logs all the processing steps, critical parameters and events in computer records. Data obtained during each process cycle can be interpreted in the form of a graph given below as Fig. 8.

![Fig. 8 Computer generated graph depicting temperature change in retort and pouch](image-url)
These systems have the built-in thermal process intelligence to safely reduce the sterilization cycle. These systems execute a self-test and check all field devices and sensors including the supplies of steam, air and water at process startup. The continuous monitoring of all critical inputs, as well as the built-in crosscheck of the retort, thermometer and the chart recorder temperature maximize a consistent process delivery. Each sterilization process is recorded in its entirety including each processing step, all critical process parameters (temperature, pressure, etc.), all process alarms, as well as all operator interventions and inputs. These computer-based process records meet HACCP requirements and are unconditionally accepted by FDA and USDA and eliminate the need for handwritten records and manual data keeping.

4.0 RETORT PROCESSING OF DAIRY PRODUCTS

The most common milk product manufactured in a retort is evaporated milk. A typical sterilization treatment for this product is 117°C for 15 min (Seehafer, 1967). A heated flavour develops often described as 'scorched', accompanied by a brownish colour. Sterilization for evaporated milk has been practiced since long and this helps to increase the viscosity and improves the body so as to give a creamy consistency to the finished product. Commercial evaporated milk remains acceptable for 2 years when stored below 16°C.

Kheer or payasam, a cereal-based particulate dairy dessert is popular throughout India. However it has a limited shelf life even under refrigeration. Many attempts have been made to enhance its shelf life in the past. Recently, a process has been developed for cooking and sterilization of kheer in retort pouches with the objective to enhance its shelf life at ambient temperature. Sterilization was done in steam-air environment, using a Millwall Model 24 Rotary Pilot Scale Retorting System employing a constant rotation of 2 rpm. Time-temperature data were recorded during heat processing using an Ellab data recorder which could compute process lethality in terms of $F_0$ value every minute. As a result of shelf life studies, it has been established that the in-package sterilized kheer has a shelf life of more than 4 months at 37°C (Jha et al., 2000).

5.0 CONCLUSION

The primary object of the thermal processing of canned foods is to destroy living organisms capable of causing deterioration of the food or endangering the health of the consumer. Coincidental with this is the necessity of retaining the organoleptic and nutritive properties to the greatest possible extent and the need for scientific adjustment of heat processes arises because a process, which is adequate from the culinary point of view, may be insufficient to eliminate spoilage organisms. The extent to which canned foods may be heated to achieve a compromise between these needs must be known and defined. There is a scope of using the basic principles of thermal processing for developing newer products as well as for enhancing the shelf-stability of existing products. In the context of renewed interest on extending the shelf life of various Indian dairy products and their large-scale manufacturing and marketing in ready-to-serve form, thermal processing assumes greater significance.
6.0 REFERENCES

1.0 INTRODUCTION

Ohmic heating also called resistance heating, Joule heating or electroheating is based on the passage of alternating electrical current through a food product that serves as an electrical resistance. The electrical power introduced into the product is transferred into heat. The heating occurs in the form internal energy generation within the material. Ohmic heating is distinguished from other modes of heating either by the presence of electrodes containing the food (as opposed to microwave and inductive heating, where electrodes are absent), frequency (unrestricted, except for the specially assigned radio or microwave frequency range), and wave-form (also unrestricted, although typically sinusoidal). When combined with an aseptic container or bag-in-box filling system, this process is capable of producing high added-value ready prepared meal products with long shelf life at ambient temperature. This paper deals with the concept of ohmic heating, its advantages, problems with its commercial installations and future potential as a means of food preservation.

2.0 OHMIC PROCESS

The basic principle of Ohmic heating is the passage of an electrical current through an electrically conducting food product, which is shown in Fig. 1. This passage of current generates heat due to the electrical resistance of the food (Skudder, 1989).

In practice, low-frequency alternating current (50 or 60 Hz) from the public mains supply is used.
3.0 THEORETICAL CONSIDERATIONS IN OHMIC HEATING PROCESS

Ohmic heating process design is based on a constant temperature throughout the holding tube and a measurable minimum temperature (i.e. the fluid temperature) at the end of the final heater. For the fluid temperature to be accepted as the minimum product temperature in the holding tube, the process design must demonstrate that the cold spot of the slowest heating particle is the same as or higher than that of the liquid when it enters the holding tube, and that the product has uniform fluid temperature at the inlet of the holding tube. If a process can be developed this way, it means that the process time would be calculated as is now done for continuous aseptically processed homogenous products. The lethal treatment would be a combination of the time in the holding tube and its temperature steady state condition.

![Fig. 2 (a) Formulation where the particle heats faster than the liquid](image)

![Fig. 2 (b) Formulation where the particle heats slower than the liquid](image)

Fig. 2 Simulated temperature profile of the slowest heating fluid temperature and slowest heating particle temperature for an ohmically heated multiphase food.

Fig. 2 (a) represents a possible temperature profile for a product for which measurable minimum temperature exists at the inlet to the holding tube. When
compared to a more transient heated particle system where the slowest heating portion of the product starts to heat in the heater and continues to heat in the holding tube (Fig. 2b), it becomes apparent that the establishment of a process similar to that in Fig. 2a is relatively easy compared to establishment of a process similar to that in Fig. 2b.

For the process in Fig. 2a conservative assumption of the holding tube entrance temperature being fixed throughout the holding tube allows for an accurate and less complex establishment of the delivered lethality. On the other hand, the process depicted in Fig. 2b indicates a time dependent temperature, which requires either a biological validation or validated mathematical model to establish the process.

4.0 DESIGN OF THE OHMIC HEATER

The Ohmic heater column typically consists of four or more electrode housings machined from a solid block of PTFE and encased in stainless steel, each containing a single cantilever electrode. The electrode housings are connected using stainless steel spacer tubes with an electrically insulating liner. Suitable lining materials include polyvinylidene fluoride (PVDF), polyether ether ketone (PEEK) or glass. The column is mounted in a vertical or near-vertical position with the flow of product in an upward direction. A vent valve positioned at the top of the heater ensures the column is always full. The column is configured such that each heating section has the same electrical impedance and hence the interconnecting tubes generally increase in length towards the outlet. This is because the electrical conductivity of food products usually increases with increase in temperature. A schematic diagram of the design of Ohmic heater is given in Fig. 3 below:

![Fig. 3 Design of an ohmic heater](image)

The longer the food stays in the electrical field, or ohmic column, the greater the amount of heat generated. A viscous food product containing particulates enters the continuous-flow ohmic heating system via a feed pump hopper. The product then flows vertically past a series of electrodes in the ohmic column, where it is heated to process temperature. Then the product enters the holding tube(s) for a fixed time to
achieve commercial sterility. The actual dimension of the ohmic heater range from a 6 feet long tube with an external diameter of 3 inch for heating thousands of gallons/hr to a less than 1 feet tube with an external diameter of 2 inch for heating hundreds of litres/hr. Typical internal diameters of the tubes are 1 inch for the large unit and 1/8 inch for the small one.

4.1 Temperature control

Commercial ohmic heating plants are available with a fully automatic temperature control system. Inlet changes that will affect the final product outlet temperature are as under:

- Changes in inlet temperature
- Mass flow rate
- Product specific heat capacity

In the control system, a microprocessor scans these variables and continuously computes the electrical power required to heat the product and compares this value with the signal from a power transducer on the output side of the transformer.

4.2 Electrolysis

Alternating current at low frequency such as 50 and 60 cycles has an electrolytic effect similar to that of direct current though to a lesser extent. The major electrolytic effect is the dissolution of the metallic electrodes, which may contaminate the product. One way to overcome this problem is to utilize high frequency. At alternating frequencies above 100 kHz, there is no apparent metal dissolution. Stainless steel electrodes for operating more than 3 years in the industry show no marks of any metal dissolution and no need for replacement.

4.3 Electrical resistance

The specific resistance is the electrical resistance of the product between two 1 cm$^2$ electrodes located 1 cm apart. Unlike metals, where the resistance increases with temperature, this specific resistance decreases with temperature by a factor of 2-3 over a 120$^\circ$C temperature rise. The actual resistance of the ohmic heating device is a function of specific resistance of the product and the geometry of the device:

$$ R = \frac{(Rs)(d)}{(A)} $$

where

- $R$ = total resistance of the device in ohm
- $Rs$ = specific resistance in ohm cm
- $D$ = distance between the electrodes in cm
- $A$ = area of the electrodes in cm$^2$

4.4 Power considerations

The heating requirement per hour is calculated by multiplying the mass flow rate ($M$) in kg/hr by the specific heat ($C_p$) in kcal/kg$^\circ$C and the temperature rise in $^\circ$C is given by:
\[ Q = MC_p \Delta T \]  \hspace{1cm} (2)

where, \( Q \) = temperature rise in °C
\( \Delta T \) = temperature gradient

The value of the total current divided by critical current density will indicate the area of the electrodes.

4.5 Voltage

The maximum standard power line is 460 ± 20 V in most countries. Using this low voltage will require high currents to achieve the required power. The power specification of the transformers should be about 30% higher than the power requirement. This will compensate for minor changes in power demand, eliminate the need to use the maximum voltage and current, and allow some flexibility in the design of the ohmic heater.

4.6 Current density

It is the current divided by the area of the electrode. Every product has specific current density above which arcing is likely to occur. Ideally a low total current should be utilized. This requires a high resistance, which dictates a small cross-sectional area and/or a long distance between the electrodes. Changing the distance without changing the area will increase the resistance and the volume between the electrodes but will also increase the power which means that the temperature will not rise to the desired level.

4.7 Velocity and heating rate

In ohmic heating the energy is introduced by the electrical current, which flows at the speed of light. The velocity and the resulting turbulence in conventional systems facilitate rapid mixing and therefore enhance heat transfer by maintaining a maximal temperature gradient. In ohmic heating of homogeneous fluids there is no temperature gradient, since the temperature is uniform across the cross section of flow. Compared to the velocity of the electrical current, the velocity of the product is negligible, and the current flows as if the product is still.

4.8 Holding time

Ohmic heating is usually used for pasteurization and sterilization of foods and other biological products. The product has to be held at peak temperature for a certain period of time to ensure the desired level of bacterial kill. Ohmic heating the product to the same temperature as in conventional heat transfer technology will demand the same or shorter holding time.

5.0 FACTORS AFFECTING EFFICIENCY OF OHMIC HEATING PROCESS

5.1 Particulates

Particulates are the centerpiece around which an ohmic formulation is built. Various combinations of meats, vegetables, pasta and fruits can be successfully
processed when accompanied by an appropriate carrier medium and suitable process controls. Fundamental particulate considerations include size, shape, concentration, density, conductivity and specific heat capacity. Optimizing the correct combination of these characteristics result in excellent texture through uniformity of particulate heating.

5.2 Particulate size

Particulate size is typically limited to 1in$^3$ for at least three reasons namely:

- To ensure that sufficient clearance past the electrodes is maintained during flow through the ohmic system
- Aseptic particulate fillers are capable of filling particulates up to 1in$^3$ without damage to the product
- Consumer response suggest that particulate larger than 1in$^3$ would require cutting prior to consuming and thereby reduce convenience

As particulate increase in size, surface to volume ratio decreases. This reduces thermal heating while maximizing ohmic heating.

5.3 Particulate shape

Particulate shape can be diverse as the variability of incoming raw materials. A variety of geometries, including cubes, spheres, discs, rods, rectangles and twists have been processed successfully.

5.4 Particulate concentration

In most ohmic formulations ranges from 20 to 70%. Extremely low or high concentration require special consideration of size, shape and texture to optimize stability of the formulation during processing. Higher concentration can be processed if the particulate are pliable and small and their geometry is varied, as this decrease the voids between particles. Lower concentration generally require a higher-viscosity carrier medium to maintain to particulate suspension. Careful evaluation of particulate size, shape and density will determine minimal particulate concentration level.

5.5 Carrier-medium viscosity

Carrier-medium viscosity is typically low when formulations containing a high concentration of particulate are processed. Conversely, carrier medium viscosity tends to be high when mixtures with low particulate concentration are processed. If the viscosity is inadequate, or if significant thinning occurs during processing, particulates may settle and/or sauce may flow past the particulates without suspending them. Changes in viscosity during processing, such as starch gelatinization or release of moisture from particulates can also result in unevenness of heating. Thickening agents should not undergo phase changes during processing, so it is important to pregelatinize starches prior to processing. It is also critical to develop formulations that maintain relatively constant viscosity within the carrier medium when utilizing particulates prone to moisture release.
5.6 Conductivity

Ohmic heating rates are critically dependent on the electrical conductivity of the food being processed. Because most foods contain a percentage of free water with dissolved ionic salts or acids, they possess electrical conductivity. Generally speaking, electrical conductivity increases with increasing temperature. Key conductivity considerations include product profiles, particulate and carrier-medium differences and the presence of nonconductive materials.

5.7 Conductivity profiles

Conductivity differences between the particulates and carrier medium need to be minimized achieve evenness of heating. Particulates are presumed to heat faster than the carrier medium when their conductivities are lower. Conversely, particulates are thought to heat slower than the carrier medium when their conductivities are higher. Generally, most particulates have lower conductivity and thus are likely to heat faster than their respective carrier mediums. These relationships are based on the particulates and carrier medium.

5.8 Nonconductive materials

Such as fat, oil, nuts, air, alcohol, bone, and ice should be minimized. These non-conducting materials will not be heated by electrical resistance. Heating is by thermal conduction instead. In addition, localized overheating can occur in conducting regions near the exterior of the non-conducting materials. Consequently, large portions of those non-conducting materials can have deleterious effects on the evenness of product heating and should therefore be minimized through careful selection of raw materials.

5.9 Specific heat capacity

When particulates and carrier medium have comparable conductivities the temperature rise will depend on the specific heat capacities. The component with the lower heat capacity (primarily the lower-moisture constituent will tend to heat faster. Typically, particulates tend to have lower heat capacities than the carrier medium (because of lower moisture content) and thus heat faster even when formulated to similar conductivities. This is of significant importance from regulatory point of view, as system temperature probes monitor the temperature of the carrier medium rather than the particulates. Thus, when the carrier medium is at process temperature, it is likely that the particulates are at a similar or higher temperature.

6.0 ADVANTAGES AND APPLICABILITY OF OHMIC HEATING

The principle advantage of ohmic heating is its ability to heat materials rapidly and uniformly, including products containing particulates. It reduces the total thermal abuse to the product in comparison to the conventional heating where time must be allowed for heat penetration to occur to the center of a material and particulates heat slower than the fluid phase of a food. In ohmic heating, particulates can be made to
heat faster than fluids by appropriately formulating the ionic contents of the fluid and particulate phase to ensure the appropriate levels of electrical conductivity. Some of the advantages of the ohmic process are enumerated below:

- Higher energy conversion efficiency (90-93%) than microwave heating (60-65%)
- No hot heat transfer surfaces hence reducing the risk of fouling
- Product does not experience a large temperature gradient
- No over-processing of liquid phase in particulate products
- No mechanical agitation to damage the product integrity
- Instantaneous start up and shut down
- Easy to control, quiet in operation
- Low maintenance cost
- Compact
- Few restrictions on scale up
- Potential savings in processing and packaging costs
- Ability to produce high added-value recipe dishes
- Wide range of packaging options

Typical examples of certain value added food products, which have been successfully sterilized using ohmic heater, are given below in Table 1.

Table 1  Value added food products sterilized using ohmic heater

<table>
<thead>
<tr>
<th>High acid products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
</tr>
<tr>
<td>Ratatouille, Pasta sauce with vegetables, vegetables</td>
</tr>
<tr>
<td>provencale</td>
</tr>
<tr>
<td>Fruits</td>
</tr>
<tr>
<td>Fruit compote, Strawberries, apple sauce, Kiwi fruit</td>
</tr>
<tr>
<td>Low acid products</td>
</tr>
<tr>
<td>Pasta</td>
</tr>
<tr>
<td>Tortellini in tomato sauce, Cappaletti in basil sauce</td>
</tr>
<tr>
<td>Meat</td>
</tr>
<tr>
<td>Beef bourguignone, Beijing lamb, beef and vegetable stew</td>
</tr>
<tr>
<td>Vegetable curry</td>
</tr>
<tr>
<td>Vegetable curry, soup concentrate</td>
</tr>
</tbody>
</table>

Ohmic heating is currently being used for the processing of whole fruits in Japan and the UK. One commercial facility in the USA is using this process for liquid egg. A large number of potential future applications exist for ohmic heating, including its use in blanching, evaporation, dehydration, fermentation and extraction and heat treatment for microbial control.

7.0  LIMITATIONS OF OHMIC HEATING PROCESS

It cannot be used for all food products. The applicability of ohmic heating depends on each product’s electrical conductivity and on whether a product is an insulator or a conductor. Insulators cannot be heated with ohmic heater. Some insulators include non-ionized fluids such as bone, fats, oils and alcohol. The ohmic heater generally cannot be used to heat tap water unless some salts are added to increase the conductivity. Ohmic process cannot be used to create a phase change
such as gelatinizing starches or other stabilizers. Starches must be pre-gelatinize prior to processing.

8.0 CONCLUSION

As a means of food preservation, ohmic heating provides the food processor immense opportunities to manufacture high value-added, shelf-stable products with a high quality. The ability to heat particulates uniformly, without mechanical damage, combined with lower nutrient and vitamin losses will ensure that ohmic heating will play a major role in the growing requirement for food products containing large particulates. Use of this processing method vis-à-vis with other conventional methods will be governed by cost considerations and suitability for specific products. It will be interesting to study the prospect of this technology for commercial manufacture of our own indigenous dairy/food products, especially those with small/large particulates.

9.0 REFERENCES

1.0 INTRODUCTION

Many food preservation methods have at their roots, findings reported long ago. Even the so-called ‘new’ techniques seem to have revealed their food processing potential in observations made a hundred years or more back. Accordingly, the origin of application of high hydrostatic pressure (HHP) for food preservation is traced back to 1899 when B.H. Hite first reported reduction of spoilage organisms in milk by HHP treatment, which was later extended to other foods such as fruits, vegetables and meat products.

Inactivation of spoilage organisms without excessively raising the temperature has been the basis of the food preservation application of HHP, but textural modification without resorting to thermal processing seems to be an added advantage in case of many foods, which in fact is one of the main reasons for resurgence of HHP as a ‘new’ or ‘non-conventional’ technology in food processing. The engineering and related aspects of HHP technology have been discussed elsewhere in this compendium. The present lecture deals essentially with the microbial inactivation and other effects of HHP in foods, with special reference to dairy applications of this new technology which is characterized by little or no chemical effects in the food. It thus relates to the ‘minimal processing’ approach which of late has been attracting increasing attention of food processors and consumers.

2.0 HHP-INDUCED INACTIVATION OF MICROORGANISMS

2.1 Mechanism

High hydrostatic pressure has been reported to induce several changes in microbial cells e.g. alterations in morphology, cell membrane, biochemical reactions, genetic mechanisms etc. Morphological changes include collapse of intracellular gas vacuoles at as low pressure as 6 bar. Cell wall damage and alterations in cellular constituents such as mitochondria have been reported in yeasts subjected to pressures higher than 2,000 bar (200 MPa). Opening and disruption of membrane pores in the nucleus have also been observed. Separation of the cell wall and damage to the intermediate layer between the cell wall and the cytoplasmic membrane are among the other cellular changes caused by HHP treatment.

High-pressure induced dysfunction of microbial cells is believed to be associated also with reduced activity of ATPase due either to its denaturation or dislocation in the membrane. The decreased ATPase activity would lead to reduced hydrolysis of ATP with a consequent increase in the internal pH and thereby inactivation of the cell.
Denaturation and ionization of proteins, and precipitation of protein complexes in microbial cells are also related to the lethal effects of hydrostatic pressure. The greater resistance to pressure in spores as compared to that in vegetative cells has been stated to be due to the protective effects of dipicolinic acid against solvation and excessive ionisation in the former.

2.2 Barotolerance of microorganisms

Sensitivity of microorganisms to hydrostatic pressure is believed to be higher in the early log phase of growth than in the stationary or dormant growth phase. Thus a decreased water activity (below 0.90) presumably resulting into transformation of the vegetative microbes from their log growth phase to dormant state has been found to coincide with increased barotolerance. It is also likely that spores have their core in a highly viscous glassy state which contributes to their enhanced resistance to pressure caused changes. Thus in one study, vegetative cells were killed at 6070 bar, but spores required a treatment at twice the pressure. Of course, the type of organism would actually determine the resistance to pressure-induced inactivation as, for example, spores of \textit{Bacillus subtilis} could survive a pressure higher than 17,240 bar (250,000 psi) for 45 min.

The lethal effect of pressure is more pronounced in the solid phase than in the liquid phase of water. Further, a neutral pH is more protective than acid pH. However, barotolerance under acid or alkaline conditions is improved when salt or glucose is present in the medium.

As for microbial resistance to other environmental stresses, barotolerance of gram-positive bacteria is greater than that of gram-negative cells. Among pathogenic non-sporeforming gram-positive bacteria, \textit{Staphylococcus aureus} is highly barotolerant. Among gram-negative non-sporeformers, certain strains of \textit{Salmonella} spp. and \textit{E. coli} 0157:H7 have high tolerance to pressure treatment.

While $10^6$ cfu/ml of the gram-positive pathogen, \textit{Listeria monocytogenes} in buffer at 23°C could be inactivated by 20 min pressurization at 3,450 bar, a similar population of another food-borne pathogen \textit{Vibrio parahaemolyticus}, a marine bacterium in clam juice required 10 min at 1,730 bar for complete inactivation. Presence of proteins, carbohydrates or lipids in a phosphate buffer has been noted to protect \textit{Listeria} against pressure inactivation. \textit{L. monocytogenes} is more resistant in milk than in buffer. In phosphate buffer \textit{Yersinia enterocolitica} decreased by 5 log cycles in 15 min at 2,750 bar, \textit{Salmonella typhimurium} at 3,500 bar, \textit{Salmonella enteritidis} at 4,500 bar, and \textit{S. aureus} and \textit{E. coli} 0157: H7 at 7,000 bar. These organisms were more resistant to hydrostatic pressure in UHT milk than in meat or buffer. HHP in combination with low pH (pH 3.0 – 4.0) was more effective against \textit{L. monocytogenes} in citrate buffer.

\textit{Listeria innocua}, a non-pathogenic gram-positive organism having physiology and resistance very similar to that of the pathogenic \textit{L. monocytogenes}, has been suggested as the indicator organism surrogate to the latter in HHP processing. An \textit{L. innocua} population of $10^7$-$10^8$ cfu/ml in ewe’s milk has been found to be completely inactivated in 15 min at 4,500 bar. It should, however, be noted that certain strains of \textit{L. monocytogenes} may not be completely eliminated even after 30 min. treatment
at 4,500 bar. Further, a non-pathogenic *E. coli* strain could serve as an indicator organism in lieu of the pathogenic strain *0157: H7*. *E. coli* in ewe’s milk has been found to be more pressure resistant than *Pseudomonas fluorescens*.

Pre-treatment with biopolymers such as chitosan and lysozyme could enhance pressure-induced inactivation of *E. coli*, *S. aureus* and *Saccharomyces cerevisiae*. The lethality of HHP treatment on *L. innocua* could be increased by the presence of ethanol and sodium sulphite.

With regard to inactivation of spores during HHP treatment, the effect of pressure on spore germination prior to destruction is important; pre-treatment at relatively low pressures (600-1,000 bar) has been found to accelerate inactivation of spores at high pressure. In one study, activation of *Bacillus subtilis* spores in milk exposed to 2,000 bar at 25-60°C showed greater germination than that at 80°C. The sporulation temperature has been found to influence the barotolerance of spore-forming bacteria. *B. cereus* sporulated at 20°C is more pressure-resistant than that sporulated at 37°C. This has been ascribed to the mechanism of pressure inactivation, which involves spore germination preceding destruction.

Sensitivity of microorganisms to pressure is usually enhanced at higher-than-ambient temperatures, mild heat treatment being synergistic with the pressure treatment. The D-value for gram-positive spore formers is 280 min at 3.5 bar and 100°C but only 2.2 min at 1380 bar and 100°C. *L. innocua* 910 CECT in milk (10⁷ – 10⁸ cfu/ml) was found to be more effectively inactivated by pressure treatment at 50°C than at 25°C, complete inactivation being achieved at 3,500 and 2,500 bar at respective temperature, in 15 min.

Inactivation of bacterial spores in low-acid foods particularly requires the combined (barothermal) treatment unless pressures in excess of 8,000 bar are used. In case of *Bacillus stearothermophilus* spores little inactivation took place at 1 bar and 90°C or 4,000 bar 20°C, but marked reduction in number (from 3 x 10⁶ to < 10 cfu/ml ) was observed when treatments were carried out at 2,000-4,000 bar and 60-90°C. However, in another study the viable count of this sporeformer could not be reduced from initial 10⁶ spores/ml to below 10²/ml even after 50 min at 120°C and 4,000 bar.

While the vegetative forms of heat sensitive moulds viz. *Byssochlamys nivea* and *B. fulva* were inactivated by exposure to 3,000 bar at 25°C within a few minutes, ascospores of *B. Nivea* and *Eupenicillium* required 6,000 bar at 60°C for 60 min for complete inactivation. Furthermore, pH in the range of 4.0 - 7.0 had little effect on pressure inactivation of *Byssochlamys* spp., but ascospores exhibited greater sensitivity to pressure at low water activities (a_w = 0.89).

### 3.0 EFFECT OF HHP ON MAJOR CONSTITUENTS OF FOODS

Water, a major food component, undergoes volume reduction of up to 15% when subjected to 6,000 bar pressure. Food containing substantial amounts of gases would go extensive compression, but those containing more water and little gas have a compressibility similar to water. Freezing point of water is known to decrease under pressure. Therefore, low-temperature pressurization of foods can have, upon depressurisation, rapid and uniform nucleation, and formation of smaller
ice crystals, which would be desirable from the texture point of view. Enhanced freezing rates is an added advantage. Different polymorphs of ice can be achieved in food either by subjecting food containing liquid water to high pressure and then cooling to the required temperature, or by pressurizing frozen food. Depressurization of food subjected to high pressure and sub-zero temperature can result in phase transitions of water which can be controlled through treatment conditions, so that desired physical properties can be imparted to the food.

HHP treatment of water-containing foods would result in a decrease in pH such as a reduction of up to 0.7 pH units caused by 4,000 bar. High pressure is believed to affect only the non-covalent bonds in food constituents, and therefore, does not produce chemical changes such as production of new compounds. However, compounds such as protein owing their structure and functional properties to hydrogen bonds, ionic bonds and hydrophobic interactions are likely to have their properties altered by HHP treatment. Thus, high pressures such as 4,000-6,000 bar can cause denaturation, gelation, precipitation, aggregation and coagulation of proteins. The structural changes in proteins may lead to their altered accessibility by digestive enzymes.

Unsaturated fat is susceptible to autoxidation whereas starch to gelatinization under the influence of high pressure. Since enzymes are by and large resistant to pressure-induced changes, thermal treatments may become necessary an adjunct treatment in foods prone to enzymatic changes.

4.0 HHP APPLICATIONS

4.1 Food applications

HHP-processed jams, fruit juices, sauces, pickles, rice, seaweeds etc. are being marketed commercially in Japan. Many food applications of HHP have been studied and their potential explored in other countries. HHP treatment (3,000-5,000 bar) has been associated with bitterness-free grape juice, better colour and flavour retention in jams and fruits such as pears, guava puree etc., improved tenderness in soybean, rice, potato etc., increased sweetness in sweet potato, improved texture in carrot (sub-zero treatment 2,000-4,000 bar), better flavour stability in sterilized tea extract (7,000 bar/50°C/30 min), enhanced colour and flavour stability in beef and reduced salt required in ham and fish paste.

Pressure-induced freezing point depression enables cryogenic or ultra-rapid freezing of foods without appreciable structural damage which is otherwise caused by slow freezing using conventional methods. Similarly, pressure-assisted thawing of foods such as frozen fish results in better quality retention. Absence of formation of ice upon freezing of water-containing foods under pressure is also the basis for sub-zero storage suggested for ensuring shelf stability without loss of textural quality. The refrigerated shelf life of fishery products could be extended appreciably by HHP treatment.

In pressure-treated eggs, the egg-white yielded a harder gel (> 6,000 bar), whereas the egg-yolk gel formed at 4,000 bar was much less hard than that formed by heating. Vitamin losses in pressure-processed egg were minimal. The HHP-treated egg did not exhibit the sulphurous flavour typical of conventionally boiled egg. Chocolate tempering and meat tenderisation are among other potential food applications of the pressurization process. Cereal grains can be pressure treated to render them quick-cooking and reduce their allergenicity.
Based on pressure inactivation of several pathogens, it has been established that acid foods (pH < 4.0) with a\textsubscript{w} = 1 can be rendered shelf stable by treatment at 5800 bar for 3 min, while food having pH between 4.0 and 4.5 would require a treatment time of 15 min. Low-acid foods, however, can be pasteurized (and freed from pathogens) by using variable pressurization time depending on type of pathogens and other factors.

4.2 Dairy applications

Extension of shelf life of raw milk by about 4 days was the first application of pressure processing (6,000 bar for 1 h at room temperature) reported by B.H. Hite in 1899. In a later study when milk was subjected to 10,340 bar at 35°C for 90 min approx. 99.95% of the microorganisms present initially were destroyed, the survivors being mainly \textit{B. subtilis}, and \textit{Bacillus alvei} spores.

Besides inactivation of microorganisms in milk and milk products, structural changes in milk proteins leading to improved functional characteristics have been of interest in recent studies relating to dairy processing applications of HHP. While disintegration of casein micelles under high pressure was reported in early studies, considerable irreversible unfolding of protein has been recently observed in skim milk subjected to a hydrostatic pressure of up to 6,000 bar for up to 120 min. With increasing pressure and duration, the exposure of hydrophilic groups on the protein surface increased. Acid-set gels (pH 4.1) obtained from such pressure-treated milk showed a higher compression strength and a higher force-at-breaking as compared to non-treated gels. Also, these gels had an improved resistance to syneresis, water holding capacity and protein hydration index.

HHP treatment of milk has been reported to increase the rate of milk coagulation attributable to the conformational changes in casein. Improved yields of cheese from pressure-treated milk have been claimed for a patented process. As an alternative to pasteurization, HHP treatment of cheese milk could help improve its rennet-clotting behaviour and product quality as well as yield. The bactericidal effect of HHP in milk has been suggested to be potentially useful in production of microbiologically safe cheese with sensory properties similar to those of raw milk cheese. A patented process relates to ripening of Cheddar cheese under pressure.

\(\beta\)-lactoglobulin is denatured at low pressures such as 1,000 bar, whereas \(\alpha\)-lactalbumin and bovine serum albumin remain unaffected by pressures up to 4,000 bar for 60 min. Proteolytic enzymes in conjunction with high pressure treatment can be employed to effect selective digestion of certain proteins such as \(\beta\)-lactoglobulin in whey or whey protein concentrates, the concomitant removal of allergenicity providing an opportunity for use of the digest in infant formulations.

Pressurization (1,000 – 5,000 bar) of 35 or 43% fat cream for 1-15 min at 23°C induced crystallization of fat within the emulsion droplets, especially at the globule periphery, and crystallization continued during further storage at 23°C unlike in non-pressurized product held at the same temperature. Such changes in cream may have application in preconditioning cream for making butter of improved spreadability.

5.0 CONCLUSION

Processing of foods under high hydrostatic pressure (HHP) leads to microbial inactivation as well as structural changes in protein, starch and other constituents. Inactivation of microorganisms is governed by, besides process conditions, many
other factors such as type, strain, and growth stage of the organism, and nature of the medium i.e. food, in term of pH, water activity etc. Although spores are more resistant to pressure than vegetative forms, considerable microbial reduction can be achieved by treatments at pressures in the range of 4,000-6,000 bar (400 – 600 MPa) without appreciable chemical changes in terms of discoloration and vitamin losses. Low-acid foods would greatly benefit from the HHP treatment coupled with a mild heat treatment. Pathogenic organisms such as *Listeria monocytogenes, E. coli. 0157 : H7* etc. need special attention with regard to the selection of the process conditions, which is likely to be influenced by the product properties.

Extensive studies have been reported in literature on potential food processing applications of HHP, but the major ones concern fruits and fish products. In fact, pressure-processed fruits, jams and fruit juices are already on Japanese markets. However, much of HHP potential remains yet to be commercially exploited. This is particularly true in the area of dairy processing. Low-temperature pasteurization of milk for fluid and product purposes is seen as a major application of high pressure. Improved textural properties together with higher yields of coagulated products including cheese can attract the heavy investment associated with HHP equipment. Perhaps the real potential of this new technology lies in novel, structurally designed dairy foods that can be obtained from HHP processed milk.

6.0 REFERENCES


1.0 INTRODUCTION

The primary objective of traditional and newly developed food preservation processes is the inhibition or inactivation of microorganisms and achieve shelf stability to food. Every food has certain inherent preservation factors such as extent of heat treatment received (F), water activity (aw), low temperature storage (t), redox potential (Eh), pH, etc. which can be termed as hurdles, because microorganisms will have to 'jump' these hurdles in order to grow and spoil the product. The stability of the product depends upon the intensity of hurdles present in it. More the intensity or height of these hurdle, or more the number of these hurdles, more difficult it will be for microorganisms to overcome these hurdles. In conventional preservation method the intensity of one or two of these hurdle is exceptionally increased making it extremely difficult for microorganisms to jump that hurdle. For example, in sterilization process F-value (i.e. the amount of heat treatment given) is increased to 3 to 15. Or in dehydration the aw is decreased to a very low value i.e. 0.85. Such extreme increase in the intensity of these parameters adversely affect the quality of certain products. Many foods can not be preserved by a single hurdle alone without affecting their sensory and nutritional properties. Paneer, for example, can be preserved for a long time by heat treatment (a single hurdle) but the immense damage to its texture and nutritive value has to be considered. Paneer's keeping quality can also be considerably extended by dehydration - a single hurdle of low aw. The result is that the dehydrated paneer's reconstitutability is poor and its texture is badly affected. However, by using three or more hurdles together, not only the damage to sensory properties is kept to the minimum, but also their synergistic action is exploited for food preservation. Thus hurdle technology is a technology by which every preservation parameter is used at an optimum level in order to get a maximum microbial inactivation by a combination of two or more such parameters so that damage to the sensory properties of food is kept to the minimum.

The hurdle effect is of fundamental importance for food preservation, since it governs microbial food poisoning as well as spoilage and fermentation of foods. Figure 1 illustrates the hurdle concept in a simplified fashion, which gives eight examples. Example 1 illustrates the principle and represents a food which contains six hurdles (i.e. f, t, aw, pH, Eh, and preservatives). The microorganisms present cannot overcome (overjump) these hurdles, thus the food is microbiologically stable and safe. However, example 1 is only a theoretical case, because all hurdles are of same height, i.e. have the same intensity. A more likely situation is presented in Example 2, since the microbial stability of this product is based on hurdles of different intensity. In this product the main hurdles are the aw and preservatives, while other less important hurdles are storage temperature, pH and redox potential.
These five hurdles are sufficient to inhibit the usual types and numbers of organisms associated with such a product. If there are only a few microorganisms present at the start (Example 3), then a few or low hurdles are sufficient for the stability of the product. The aseptic packaging of perishable foods is based on this principle. On the other hand, as in Example 4, if due to bad hygienic conditions too many undesirable microorganisms are initially present, even the usual hurdles inherent in a product cannot prevent spoilage or food poisoning.

Example 5 is a food superior in nutrients and vitamins, which foster the growth of microorganisms, and thus the hurdles in such products must be enhanced, otherwise they will be overcome. Example 6 illustrates the behaviour of sublethally damaged organisms in foods. It, for instance, bacterial spores in food products are damaged sublethally by heat, then the vegetative cell derived from such spores lack vitality, and therefore are already inhibited by fewer or lower hurdles. In some foods, such as fermented sausages, the microbial stability is achieved during processing by a sequence of hurdles (Example 7). Also in the processing and storage of cheese, a sequence of hurdles is responsible for microbial stability.

Finally Example 8 should illustrate an important phenomenon, which deserves particular attention in foods preserved by combined methods, because different hurdles in a food might not just have an additive effect on stability, but could act synergistically. A synergistic effect of hurdles is to be expected if the different factors (e.g. pH, Eh, \( a_w \), preservative, etc.) have different targets within the microbial cell, and thus disturb the homeostasis in several respects. This could make it difficult for spoilage or food poisoning organisms to overcome the lag-phase, and if multiplication is delayed the microorganisms eventually die (Leistner, 1985).

### 2.0 EFFECT OF HURDLES ON MICROBIAL GROWTH

In commercial products the objective is to destroy the spores, however, in hurdle technology foods the aim is to apply heat sufficient to kill all vegetative cells and then inhibit or delay the germination and growth of spores by controlling other hurdles such as water activity, redox potential, pH, etc. The growth of *Staphylococcus aureus* and *Bacillus subtilis* was shown to be prevented up to 42 days by the combined inhibiting effect of \( a_w 0.94 \) pH 5.5-sodium benzoate 2000 ppm, while individually these parameters were effective only up to 3 days. These interaction effects were recommended to be used in comminuted meat products (Webster et al., 1985). The combinations of \( a_w 0.925 \) pH 5.0 or \( a_w 0.915 \) pH 5.5 or \( a_w 0.90 \) pH 6.0 together with addition of sodium nitrite were also stated to result in synergistic growth inhibition of *Staphylococcus aureus* (Martinez et al., 1986). Thayer et al. (1987) studied the effect of NaCl, pH, temperature and atmosphere on the growth of *Salmonella typhimurium* and showed that aerobic growth was reduced from 9.16 log viable count at 37°C-pH 7.0-NaCl 1.0 percent to 0.735 at 19°C-pH 5.0-NaCl 5.0 percent indicating additive effect of NaCl, pH and temperature.

Rao (1993) studied the combined effect of \( a_w \), pH, heat treatment and potassium sorbate on survival of *Bacillus subtilis* spore during heat treatment of fried paneer and their growth during subsequent storage at 30°C. During processing of paneer at F-value of 0.8, maximum numbers of survivors were noticed at \( a_w 0.90-0.93 \) and pH 5.2-6.0 and the minimum survivors in the range of \( a_w 0.95-0.98 \) and pH
5.0 - 4.4. During storage of paneer he observed maximum growth rate of *B. subtilis* at $a_w$ 0.96-0.98 and pH 5.2-6.0 and lower growth rates at $a_w$ 0.93-0.90 and pH 4.4-5.0. He developed mathematical equations to predict the combined effect of hurdles on bacterial growth.

### 3.0 EFFECT OF HURDLES ON PHYSICO-CHEMICAL CHANGES IN FOOD

Rao (1993) was probably the first to show that the combined effect of hurdles not only influence the microbial growth during storage but also influence the physico-chemical changes. The combined effect of $a_w$, pH, F and potassium sorbate on oxidation, browning and hardness of paneer during storage was studied in greater detail.

### 4.0 HURDLE TECHNOLOGY FOODS

Foods preserved by hurdle technology are grouped as hurdle technology foods. Several shelf stable foods have been either newly formulated or upgraded on the lines of hurdle technology. Recently, an encyclopaedia was published describing the characteristics and preservation principles of long life traditional meat and dairy products of Latin American countries. It is significant to note that many dairy products resembled Indian dairy products. Indian dairy products can also be upgraded on lines of hurdle technology to achieve greater shelf stability. Leistner (1985) reported a number of shelf stable products (SSP) based on hurdle technology. These were classified according to the main hurdle in them like F-SSP, pH-SSP, $a_w$-SSP, etc.

#### 4.1 F-SSP

The primary reason for stability of F-SSP, is the inactivation or sublethal damage of bacterial spores. The products are given only a relatively mild heat treatment (F value 0.4), which inactivates all vegetative microorganisms and sublethally damages spores. Bacteria deriving from such spores have a diminished vitality, and therefore are already inhibited by $a_w$ and pH values that are not detrimental to the sensory properties of the products. A low Eh contributes further to stability. The $a_w$ of F-SSP must be lower than 0.96. The pH of F-SSP should be between 6.0 to 6.5. The processes of certain indigenous dairy products like kheer, khoa, basundi, rabdi, etc. can be upgraded on lines of F-SSP.

#### 4.2 $a_w$-SSP

For stable and safe products of the $a_w$-SSP type, the following guidelines must be observed: $a_w$-SSP should be heated to an internal temperature of at least 75°C in a sealed container. The water activity of $a_w$-SSP must be adjusted to below 0.95. Thus, a lower $a_w$ is more essential than in F-SSP, because of the milder heat treatment of $a_w$-SSP the bacterial spores are damaged less than in F-SSP. The Eh of the product should be low, because a reduced redox potential contributes to the growth inhibition of $a_w$ tolerant bacilli. Smoke or potassium sorbate treatment or vacuum packaging of products is necessary to prevent mould growth. The Italian Mortadella and German Bruhdauerwurst are the typical examples of $a_w$-SSP. The processes for the manufacture of peda, burfi, kalakand, sandesh, rasogolla and gulabjamun could be redesigned according to $a_w$-SSP hurdle technology.
4.3 pH-SSP

In such products vegetative microorganisms are inactivated by heat and the multiplication of surviving bacilli and clostridia is inhibited by the low pH. In this process the product having pH less than 5.0 and water activity around 0.98 is filled in containers and heated to an internal temperature of at least 72°C but not higher than 80°C. Pasteurized fruit and vegetable preserves and jelly sausages are the examples of pH-SSP. Thermised shrikhand is the indigenous product of this group.

4.4 Combi-SSP

Some SSP are stabilized by several hurdles which have to be well balanced with each other. Even small enhancements of the individual hurdles in a food in summation have a definite effect on the microbial stability of a product. Every small improvements or reinforcements of a hurdle bring some weight on a balance, and the sum of these weights determines whether a food is microbiologically unstable, uncertain, or stable. In other words, all little steps in the direction of stability will finally decide whether the balance swings from an unstable into a stable state of a product. As an example of a combi SSP the Gelderse Rookworst could be mentioned. Rao (1993) developed a long-life paneer curry using this principle. Combi-SSP offer many opportunities for development of long life dairy products, however, they require strict process control following the HACCP concept.

5.0 HURDLE TECHNOLOGY AND FOOD DESIGN

The practical importance of the hurdle technology for stable and safe foods has now been recognized by the food industry, since an intelligent combination of hurdles secures the microbial stability as well as the sensory, nutritive, toxicological, and economic properties of a food. In food design as well as food control this principle is increasingly applied and proved very successful. This technology is now especially used for making new products according to needs. For instance, if energy saving is the goal, then energy consuming hurdles such as refrigeration are replaced by hurdles (a\textsubscript{w}, pH or Eh) which don't demand energy and still ensure a stable and safe food. For instance, it is feasible to achieve a comparable microbial stability by using additional hurdles at +10°C, instead of -1°C as chilling temperature. Similarly, an adjustment of foods to a\textsubscript{w} below 0.95 would make temperature above +100°C unnecessary in canning, since surviving spores of bacterial can not cause spoilage or food poisoning below this water activity. Furthermore, if we want to reduce or replace preservatives, we could emphasize on other hurdles in food, e.g. a\textsubscript{w}, pH, refrigeration, or competitive flora, which would stabilize the products. Food control could be based on the physical and chemical measurements of hurdles in a food and computer evaluation of the results. This approach could give faster and sometimes more reliable information on the stability and safety of foods than a microbiological evaluation.
Fig. 1 Illustration of the hurdle effect, using eight examples. Symbols are: F, heating; aw, water activity; pH, acidification; Eh, redox potential; pres, preservatives; K-F, competitive flora; V, vitamins; N, nutrients.
6.0 REFERENCES


1.0 INTRODUCTION

Natural anti-microbial systems are set to become an increasingly important component in food preservation methodology. One reason for this is that the consumers are rejecting the use of chemical preservatives but still demand foods with an acceptable shelf life. The current trend is towards less heavily preserved foods (less chemical preservatives, salt, sugar) that are not severely damaged by heat processing or freezing and do not contain artificially additives. There are many natural anti-microbial compounds that could be used in food preservation systems produced from plants, animals and microorganisms. In this article the potential anti-microbial substances derived from plants for possible application in food presentation will be discussed.

2.0 CHEMICAL DEFENCE SYSTEM IN FOOD PLANTS

The chemical defences of plants may involve both the passive use of preformed secondary metabolites (antibiotics) and dynamic, enzyme-catalysed processes that begin only after the plant has been invaded. Ingham (1973) has suggested that the plants chemical defences may be classified into preinfectional and postinfectional factors as follows (Harborne, 1993):

- Prohibitins: metabolites which slow or halt microbial growth in vivo.
- Inhibitins: metabolites which require a postinfectional increase in concentration for full effect.
- Postinhibitins: toxic metabolites formed after infection, by hydrolysis or oxidation of preformed compounds.
- Phytoalexins: anti-microbial compounds formed de novo only after invasion of the host plant.

The defensive anti-microbial compounds produced by plants are usually classified as ‘sensory metabolites” and are usually produced via five major biosynthetic routes. The major biosynthetic pathways for secondary metabolites are exemplified below:

i) Derivatives of sugar metabolism, such as inositols and the amino sugar found in many antibiotics. Many antimicrobial compounds are present in the plant as glycosides, often esterified with a wide range of unusual sugar derivatives.
ii) The acetone-malonate pathway, which leads to fatty acid derivatives such as poly acetylenes and to polyketides.
The acetate-mevalonate pathway, leading to terpenoids and steroids.

The shikimic acid pathway, this forms phenylalanine and hence leads to a vast array of aromatic and phenolic compounds.

Metabolites derived from amino acids, these include the alkaloids and non-protein amino acids.

3.0 PLANT ANTIMICROBIALS

Spices and herbs have been used for millennia to provide distinctive flavours for foods and beverages around the world. Farrell (1990) described spices as any dried, fragrant, aromatic, or pungent vegetable or plant substance, in the whole, broken, or ground form, that contributes flavour, whose primary function in food is seasoning rather than nutrition, and that may contribute relish or piquancy to foods or beverages. Spices may be the dried arilla, bark, buds, flowers, fruit, leaves, rhizomes, roots, seeds, stigmas and styles, or the entire plants tops. In addition to contributing, flavour to foods, many spices also exhibit antimicrobial activity. In many instances, concentrations of compounds in spices and herbs necessary for inhibiting microorganisms exceed those resulting from normal usage levels in foods. The spices containing antimicrobial compounds and their activities have been presented in Table 1.

Table 1. Antimicrobial Compounds Associated with Common Spices

<table>
<thead>
<tr>
<th>Spices</th>
<th>Antimicrobial Compound</th>
<th>Action</th>
<th>Microbial spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>Allicin (2-propenyl-2 propenthiole sulfinate)</td>
<td>Bactericidal, Medicinal, Antibacterial</td>
<td>B.Cereus, Staph.aureus, Candida, Torulopsis, Salmonella etc.</td>
</tr>
<tr>
<td>Onion</td>
<td>Allicin</td>
<td>Growth inhibitor Bactericidal</td>
<td>E.coli, Shigella, Enterobacter, Pseudomonas spp. etc.</td>
</tr>
<tr>
<td>Oregano</td>
<td>Thymol (5 methyl-2, 1-methylethyl phenol)</td>
<td>Inhibits growth, Germination and toxin production</td>
<td>S. typhimurium, A. flavus, Pediococcus etc.</td>
</tr>
<tr>
<td>Savory</td>
<td>Thymol</td>
<td>Antifungal, Stimulatory</td>
<td>Cl. botulinum, Aspergillus, Pediocococcus spp. Pathogenic/non-pathogenic fungi</td>
</tr>
<tr>
<td>Chinnamon</td>
<td>Cinnamic aldehyde (3-phenyl 2-propenol)</td>
<td>Inhibits mould growth and mycotoxin production</td>
<td>A.parasiticus, Staphylococcus and Bacillus etc.</td>
</tr>
<tr>
<td>Clove</td>
<td>Euganol (2 methoxy-4-2 propenyl phenol)</td>
<td>Antimycotic/ Antifungal</td>
<td>S. typhimurium, B. subtilis, Aspergillus and Staphylococcus spp.</td>
</tr>
<tr>
<td>Vanilla</td>
<td>Vanillin (4 hydroxy-3methoxy benzaldehyde)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1 Allicin

Garlic is related to onions (*Allium cepa*), leeks (*Allium porum*), Shallots (*Allium ascalonicum*), Chives (*Allium schoenoprasum*) and garlic chives (*Allium tuberosum*). Many of these species also contain active antimicrobial compounds found in garlic. Yoo and Pike (1998) analyzed the contents and relative proportion of thiosulphinates in different Allium species. Their data revealed different species of Allium contained different proportion of thiosulphinates, with *A. sativum* containing the most S-2-propenyl (allyl)-L-cysteine-sulphoxide, a 83.7% relative proportion. Giant garlic (*A. ampeloprasum*) contained 62.7% relative proportion of S-2-propenyl (allyl)-L-cysteine sulphone. Garlic has been used for medicinal purposes for centuries. Cavillito *et al*., (1945) were the first to isolate an antimicrobial component from garlic bulbs by stream distillation of ethanolic extract and identified the compound as allicin (2-propenyl-2-propenethiol sulfinate). It is a colourless pungent oil and is the principal odourant. Having the taste of garlic and onion.

Extract of Allium spp. has been reported to inhibited the growth of several food spoilage and pathogenic bacteria. Saleem and Al-Delaimy (1982) demonstrated that aqueous extract from fresh garlic bulbs at concentrations of 5% and 10% inhibited the growth of Bacillus cereus by 58.2 and 100% respectively. Garlic sap inhibits the growth of several gram positive and gram-negative food spoilage and pathogenic bacteria including Escherichia, Enterobacter, Salmonella, Shigella and Pseudomonas. Garlic oil was found to be a potent inhibitor of food poiling yeasts at concentrations as low as 25 µg/ml (Conner and Beuchart, 1984). The effect of garlic and onion oils on toxin production by *Clostridium botulinum* in meat slurry indicated that these oils at concentration 1500 µg/g inhibited toxin production. The antimycotic effects of garlic and onions have also been documented. Several species of food spoilage yeast and molds are inhibited.

3.2 Thymol

Thymol is yet another compound that has antimicrobial activity essentially present in the oil fraction of thyme, oregano and savory seeds. Thymol (5-methyl-2-(1-methylethyl) phenol) has wide spectra of antimicrobial effectiveness that is inhibitory against 25 genera of bacteria. Thymol has been shown to inhibit growth and toxin production of mycotoxigenic moulds (Akgul and Akivanc, 1988). Thymol has been reported to have a strong antifungal activity: Hitokoto *et al*., (1980) reported that an concentration of < 0.4 µg/ml thymol caused complete inhibition of the growth of *Aspergillus flavus* and *Aspergillus versicolor*. Azzouz and Bullerman (1982) reported that a 2% concentration of oregano completely inhibited growth of seven mycotoxigenic moulds and eighteen pathogenic and non-pathogenic fungi. Thyme and oregano may have stimulatory effect on lactic acid production. The effect of turmeric on the growth of intestinal and pathogenic bacteria indicated that the oil fraction of turmeric was inhibitory toward numerous bacteria including *B. cereus*, *Staph. aureus*, *E. coli* and *Lb. plantarum*. 

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3.3 Cinnamic aldehyde

Cinnamic aldehyde (3-phenyl-2-propenal) has been shown to be the major antimicrobial compound in cinnamon. In addition to exhibiting antibacterial activity, cinnamic aldehyde (3-phenyl-2-propenal) also inhibits mold growth and micotoxin production. The inhibitory effect of cinnamon on aflatoxigenic molds was reported by Bullermann (1974). He reported that 1-2% concentration of ground cinnamon eliminated almost 99% of aflatoxin production.

3.4 Eugenol

Eugenol is a major constituent of clove oil and present in considerable amounts in the essential oils of all species, Eugenol (2-methoxy-4-2-propenylphenol) possesses antimicrobial activity and is most effective against S. typhimurium, Staph. aureus and V. paraheemolyticus than thymol, anethol and menthol. Clove oil at concentration of 250 μg/ml has been reported inhibitory to growth and toxin production by several molds. Ground clove was observed to inhibit completely the growth of toxigenic Aspergilli in culture media. The rate of germination of Bacillus both by clove powder and eugenol at a concentration of 120 μg/ml and 200 μg/ml respectively (Blank et al., 1987).

3.5 Vanillin

Vanillin (4-hydroxy-3 methoxybenzaldehyde), a major constituent in vanilla beans, is structurally similar to engenol and is also antimycotic. The compound has been shown to inhibit or retard the growth of yeasts and molds.

3.6 Caffeine

Caffeine is present among the flavour compounds of coffee, tea and cocoa beans. Caffeine (1,3,7-trimethylxanthine) is antimycotic as well as antibacterial factor. Uchman et al., (1983) reported inhibition of growth of several mycotoxigenic Aspergillus and Penicillium spp. At concentrations as low as 1 μg/ml. Caffeine also adversely effected production of aflatoxins, ochratoxin, sterigmatocystin and citrinin by molds. Various modes of action of caffeine microbial cell functions have been described. Tortora et al., (1985) reported that caffeine uncoupled the regulation of glycolysis and glucogenesis in S. cerevisiae and inhibited growth of A. parasiticus due to alteration of purine metabolism. It was reported that S. aureus, B. cereus, E. coli, Streptococcus faecalis and Salmonella species failed to grow in 2% reconstituted decaffeinated and non-decaffeinated coffee. Caffeine is known to depress bacterial DNA synthesis.

3.7 Medium chain fatty acids

As antimicrobial agents, medium chain fatty acids containing 12-18 carbon atoms are most effective. The antimicrobial action of fatty acid is primarily static rather than cidal. In general, fatty acids are more effective inhibitors of gram positive bacteria and yeast, although some fatty acid derivatives reduce both growth and aflatoxin production of Aspergillus species. Kabara (1983) reported that lauric,
myristic and palmitic acids are effective inhibitors of bacteria and capric and lauric acids are most active against yeasts. The toxicities of fatty acids are determined by their chain length, degree of saturation and geometric configuration. The inhibitory activity of unsaturated fatty acids increases as the number of double bonds increases. With respect to gram positive bacteria, the most effective chain length of saturated fatty acid is 12 carbons, the most effective monounsaturated fatty acid being palmitoleic and most effective polyunsaturated fatty acids may offer potential as microbial inhibitors in slightly acid foods. However, several inherent factors other than acidity and pH of food control the effectiveness of fatty acids. Foods containing antagonists like serum albumin, starch and cholesterol etc. may not be suitable for preservation by fatty acids. Fatty acid esters of sucrose and other polyhydric alcohols also possess antimicrobial activity, thus exerting preservative effect in foods. An inhibitory effect of glycerol monolaurate on \textit{V. parahaemolytis} has been observed at concentration as low as $5 \, \mu g/ml$ (Beuchat, 1980)

Various mechanisms for the antimicrobial activity of fatty acids have been reviewed by Kabara (1983). They pointed that antimicrobial activity was due to inhibition of membrane transport, thus resulting in nutritional deprivation of cells. Gram negative bacteria appear to be less susceptible than gram positive bacteria to inhibition by fatty acids.

### 3.8 Humulones and lupulones

The female flowers of the hop vine (lupulus humulus) contain humulones and lupulones, which are used in the brewing industry to impart desirable bitter flavour and aroma to beer. Both the X and B analogues of these acids exhibit antimicrobial activity. The antymycotic effect of hop extract is influenced by water activity. It has been suggested that the combined effect of reduced $a_w$ and hop extract may be exploitable in imparting biological stability to intermediate moisture foods.

### 3.9 Other compounds

Hydroxycinnamic and cinnamic acids are phenolic compounds which are present in higher plants, often in plant parts used as spices. Those having antimicrobial activity include caffeic, chlorogenic, p-coumaric, ferulic and quinic acids. Depending upon the botanical species, hydroxycinnamic acids may be present at concentrations sufficient to retard microbial invasion and delay rotting of fruits and vegetables. Gram-positive and Gram-negative bacteria, moulds and yeasts commonly encountered as food spoilage organisms are sensitive to hydroxycinnamic acid derivates. Caffeic, ferulic and p-coumaric acids, for example, inhibit \textit{E. coli}, \textit{Staph. aureus} and \textit{B. cereus}. Food-borne pathogenic bacteria adversely affected by a wide range of compounds present in these seasoning agents include \textit{Cl. botulinum}, \textit{B. cereus}, \textit{E. coli}, \textit{List. monocytogenes}, \textit{S. typhimurium} and \textit{V. parabaemolyticus}. Growth of the mycotoxigenic moulds, \textit{A. flavus}, \textit{A. parasiticus}, \textit{A. versicolor}, \textit{Aspergillus ochraceus}, \textit{Pencillium urticae} and \textit{Pen. roquefortii}, as well
as other food spoilage moulds, yeasts and bacteria, is also retarded or inhibited in the presence of many spices and herbs commonly used as flavouring agents.

4.0 CONCLUSION

For a natural antimicrobial compound to be used as preservative in food systems, it needs to be produced economically on a large scale, it must not cause undesirable organoleptic changes and it must be toxicologically safe. The future use of natural antimicrobial agent is most likely to be coupled with other preservative systems. Natural antimicrobial compounds could also be used in combination with physical treatments, such as heating or freezing processes and hurdle technology.

5.0 REFERENCES

1.0 INTRODUCTION

The recent renewed interest in high hydrostatic pressure (HPP) technology can be attributed to two factors. First, there is an increase in consumer demand for high quality minimally processed additive-free and microbiologically safe foods. This has stimulated the food industry to investigate new food processing operations to meet this demand. Secondly, due to the progress in the technology itself, which can be adapted to the needs and demands of the food industry (Mertens and Deplace, 1993).

Substantial progress has been achieved since the revival of high-pressure research and development in the areas of food science and food technology and food biotechnology (Balny et al., 1992, Hayashi and Balny 1996, Heremans 1997, Ledward et al., 1995). Significant advancement have been made towards the understanding of mechanisms involved in the application of high pressure to food systems especially regarding microorganism and proteins and kinetic data are being accumulated required to develop and monitor products and processes as well as to provide a base for regulatory approval of high pressure based processes and products.

High pressure processing (HPP), also described as high hydrostatic pressure (HHP), or ultra high pressure (UHP) processing, subjects liquid and solid foods, with or without packaging, to pressures between 100 and 800 Mpa. Process temperature during pressure treatment can be specified from below 0° C (to minimize any effects of adiabatic heat) to above 100° C. Vessels are uniquely designed to safely withstand these pressures over many cycles. Commercial exposure times at pressure can range from a millisecond pulse (obtained by oscillating pumps) to a treatment time of over 1200 s. In contrast to thermal processing, economic requirement for throughput may limit practical exposure times to less than 20 min. Pressures used in the HPP of foods appear to have little effect on covalent bonds (Tauscher 1998; 1999); thus, foods subjected to HPP treatment at or near room temperature will not undergo significant chemical transformations due to pressure treatment itself. HPP may be combined with heat to achieve an increased rate of inactivation of microbes and enzymes. Chemical changes in the food generally will be a function of the process temperature and time selected in conjunction with the pressure treatment.

The application of high pressures for the preparation of foods is not very new and the possibilities of applying high pressure as a food processing method was first
reported a century ago by Hite for preserving milk and milk products (Hite 1899). Further, Hite and his associates adapted the potential use of high pressures for processing a wide range of foods and beverages (Hite et al., 1914). They also studied pressure inactivation of viruses (Giddings et al., 1929).

Though the attempt was remarkable, yet Hite’s work did not receive much attention. Later on various marine related studies on the effects of high pressure on microbial cells at pressure naturally occurring in biosphere (Zobell, 1964 Sleigh and Macdonald, 1972), bacterial growth at ocean depths of 11,000 meters where pressures reach 1000 atm), rapid sulfate reduction and growth at 1000 atm. by some basophilic Desulfovibrio bacteria (ZoBell, 1970) have provided significant information on the understanding of the basic mechanisms of the action of hydrostatic pressure for food preservation. In addition, the magnitude of biospheric pressure existing at some of the deepest points of ocean is approximately 1100 atm for use in food processing (although practical upper limit for commercial applications has been approximately 4000 atm).

2.0 INDUSTRIAL HIGH PRESSURE SYSTEMS

In food systems, the high pressure applied is “isostatic “ and is instantaneously and uniformly transmitted throughout the pressure medium and food product. In addition, the pressure applied is independent of the volume, shape and physical state of food (Mertens and Deplace, 1993). This process has also been termed ‘pascalization’ because it follows the Pascal’s principal (Farkas, 1993). It is also considered as a ‘cold process’, since most foods can be pressurized at ambient temperatures (Farr, 1990; Sweintek, 1992). Generally, the equipment for industrial high pressure systems include a high pressure vessel and its closure, a pressure generation system, a temperature control device and material handling system with scope for automation (Mertens and Deplace, 1993).

2.1 Pressure vessels and its closure

The pressure vessel is mainly the heart of the complete high-pressure system, which in many cases is simply a forged monolithic cylindrical vessel constructed of low-alloy steel of high tensile strength. The maximum working pressure used, vessel diameter and number of cycles for which the vessel is to be designed, decide the wall thickness. However, by using multi-layer, wire-wound or pre-stressed designs the vessel wall thickness can be reduced. Depending on the application, different vessel closure designs are used. It is the dwell time (i.e. the time of holding at a particular pressure) that decides the type of closure to be employed for a particular pressure vessel. When the dwell time at working pressure is short, for instance as in CIP (cold isostatic process) for different food applications, fast opening and closing and closing interrupted thread vessels are used. Thus, vessel downtime is minimized and vessel productivity (expressed as number of cycled per unit time) is increased which is of great importance in items of economic feasibility of the high hydrostatic pressure process. For hot isostatic process (HIP) applications, less expensive continuous thread closures are used, since the dwell time at working pressure amounts to several hours.
2.2 Pressure generation systems

Once vessel is loaded with feed material and closed, it is filled with a pressure-transmitting medium (i.e. water) along with food grade mineral or vegetable oil(s) for lubrication and anti-corrosion purposes. Initially, the vessel is evacuated at low pressures, subsequently by using a fast fill and drain pump in combination with an automatic de-aeration valve, high hydrostatic pressure is generated by direct or indirect compression or through heating of pressure medium.

Direct compression systems (Fig.1) make use of a piston driven by low-pressure pump, while indirect compression system (Fig.2) uses a pressure intensifier for pressure generation. However, in applications where high pressures in combination with elevated temperatures are required, pressure could be generated by thermal expansion of the pressure medium.

2.3 Temperature control device

The temperature of load and pressure transmitting medium inside the high pressure can be controlled in two ways. First, by using external temperature control wherein heater bands would be wound around the pressure vessel, whereas in case of internal temperature control the heat or cold source is placed inside the pressure vessel. When both heating and cooling are required, a jacket could be fitted to the vessel in which heating or cooking medium is circulated. However, thermal insulation is essential to prevent losses during operation.

2.4 Material handling system

The material handling system involves opening and closing of vessel and loading and unloading of food material. However, automation of the material handling system would be beneficial by employing automatic filling, closing and washing and automatic transport to and from the pressure vessel which increases the process efficiency and minimizes the operational cost.

3.0 PROCESS OPERATION

The HHP processing of foods can be accomplished mostly by either bulk processing followed by aseptic and sealing or by in-container processing. The advantages and disadvantages of these processes are presented in Table1. Since HHP process is a batch process, the current status of this technology allows the forging of pressure vessels with significant internal volumes as shown in Table 2. Thus, on the basis of the tabulated data, the pressure volume combinations for food applications are decided. However, using a multiple vessel combination can increase the productivity of a HHP system. Figure3 shows a pseudocontinuous process using a series of batch vessels for processing of liquid foods like milk, juices and beverages.

4.0 TYPES OF PROCESSES

The different types of high-pressure processes conventionally, being used for different commercial applications, include cold Isostatic Pressing (CIP) Warm Isostatic Processing (WIP) and Hot Isostatic Pressing (HPP).
4.1 Cold isostatic pressing (CIP)

It is essentially a forming technology, which involves compaction of powered materials like metal, ceramics, carbon or graphite and plastic (PTFE) by applying high isostatic pressures at room temperatures. Depending on types of material, the pressure to be applied range from 50 to 600 Mpa. The dwell time at a particular pressure is typically zero, ranging to a few seconds and cycle times (total time taken for material handling – time to load, unload, including time to open and close the vessel) ranging from 0.3 to 5min. Further, this process can be classified as ‘wet bag’ and ‘dry bag’ process. The difference between these two processes lies in the mode of filling the mould. In wet bag process, the mould is filled outside and then placed into pressure vessel, while in dry bag process, the mould is fixed inside the pressure vessel and filled in situ. For food applications, both dry bag (in bulk) and wet bag (in-container) processes are of interest.

4.2 Warm isostatic pressing (WIP)

In this particular process, isostatic pressures ranging from 100 to 200 Mpa in combination with temperatures ranging from ambient to 200 C are used. The dwell and cycle times here are longer than CIP process. This process is normally employed for powders that undergo a chemical reaction during compression phase.

4.3 Hot isostatic pressing (HIP)

In this process, isostatic pressures ranging from 100-400 Mpa and temperature ranges of 1000-2000 C are commonly used. The dwell and cycle times (5-10 h) are higher than that of WIP. This process is not suitable for food applications and is generally being used in metal and ceramic industries for shaping metallic and ceramic powders.

5.0 DESIGN CONSIDERATIONS FOR EQUIPMENT AND SYSTEMS FOR HIGH PRESSURE

5.1 The press

The key element for high-pressure treatment is the press. The pressures required for proper treatment of food products lie between 400 Mpa and 800 Mpa. Such pressures make extreme demands on the materials used in the press and in the pumping system. 400 Mpa is too low for most applications considering there are variations in the raw material and microbiological flora. On the other hand, 800 Mpa is often considered too costly for the treatment of food products. It has therefore decided to focus development on equipment for 600 Mpa, which is sufficiently high for treatment of all types of acidic foods and at a cost many products can afford.

5.2 Steel

When the pressure vessel is pressurized and contains high pressures, the inner wall of the vessel will experience a stress. The stress level is so high that special designs and steels must be used to contain the pressure. The pressure vessel and pumping system are subjected to pressure/stress cycling each time a
batch of food is processed. Such cycling will eventually fatigue the material and probable life length can be calculated for the design. The pressure vessel and components of the pumping system can be pre-stressed to enhance their capacity to withstand the high stresses and prolong the life expectancy.

5.3 Cost

The cost of processing food with high pressure depends on factors. The key issue to optimize the total process chain including preparation, handling, processing parameters, volumes and seasonal changes in demand or supply and reliability of the processing equipment. For the processing parameters it is essential to find combinations of pressure, time and temperature, both to achieve the desired product quality and allow for variations in raw material and to keep the cost to a minimum. The major portion of the HPP cost based on an up time of 90% is the capital cost, which then amounts to around 75%. The remaining 25% are manpower, occupancy, consumables and maintenance. If the up time falls due to failures in the pressurizing system productivity goes down quickly and maintenance increases. Key issues are therefore the up time and the utilization to the equipment.

Once shift operation is 40% more costly than two shift operation. 50% fill density is twice as costly as 85%, e.g. a round bottle with a long neck will fill 50% of a press while a six–sided bottle with a short neck will fill 75%.

The cost per processed volume is reduced with larger presses having capacity. The cost per kilo of processed product is 35% lower with a 400-L press than with a 150-L press.

Two 400-L presses with a common system will have the same production capacity as one 1000-L press. This way, the investment can be spread out in time and the capacity growth more adapted to the demand.

If the micro biological results are the same, processing at 400 Mpa with an 8 minute holes time will cost the same as using 600 Mpa and a 3 minute hold time. However the 600 Mpa unit has a higher capacity and a wider use for future expansion of products.

Before looking at the equipment to suit high pressure research up to 1400 Mpa it is important to look at the requirement and difficulties associated with such equipment, since if very high pressure applications are to be commercially viable for other than niche products the technical difficulties must be solved, or the process adapted to the technology.

As stated, typical industrial hydraulics is generally below 70 Mpa, the principal reasons being that above this pressure cost and reliability become significant factors.

Cost increases because the materials of construction must change to provide improved mechanical properties to contain the pressure, also to resist the severe erosive forces that can occur in high-pressure component. In addition as much high-pressure equipment is operating on non-corrosion inhibiting fluids materials must often be corrosion resistant.
Cost increases because the construction becomes more complex as valve and seal arrangements must be used while in much lower pressure hydraulics small clearance can be used instead.

Reliability will tend to decrease as pressures increase as seals become more prone to wear and also fatigue of materials becomes a significant wear mechanism were increased operating stresses become higher. While below 70 Mpa is possible to design systems without significant usable condition.

At less than 70 Mpa pressure erosion wear is often negligible and many components wire with a constant leak, at extreme pressure even a short duration leak can wear a component to an unusable condition.

As pressure increases to 400 Mpa the above problems become more acute but engineering solutions have been developed to meet these requirements that are high added value products.

As pressure increase above 400 Mpa the problems begin to push the existing technology to its limits and often-new solutions are required or desirable.

5.4 Safety

High-pressure equipment is often perceived as dangerous, and certainly if improperly designed or operated in an unapproved manner this could be the case, but this would apply to most laboratory tools. In general most high pressure equipment is safe but it is true to say that some designs can reduce any attendant risks and reduce the sensitivity to poor operational practices.

5.5 Reliability

This is one of the requirements of a system as good reliability is not only beneficial for the obvious reasons of less down time and lower operating costs but also the less a system requires attention the lower the risk of the poor maintenance practices and safety interlocks being by-passed.

5.6 Ease of use

It has always to be borne in mind by the manufactures that most users of the equipment are not equipment enthusiasts so the ease of use is essential.

The status of HHP technology today is such that the operating capacity, process control and safety requirement for high-pressure food processing can be readily achieved as per requirements. However, the commercial processing poses specific requirement in relation to sanitation and cleaning, package design, material handling and operational costs. In addition, the most difficult challenge for the commercial application of high pressure technology probably lies in marketing, that is identifying those applications for which the high pressure processing cost is justified by unique and superior food product properties.
Table 1 Advantages and Disadvantages of In-container and Bulk Processing Operation

<table>
<thead>
<tr>
<th>Advantages</th>
<th>In-container</th>
<th>Bulk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable to all foods, both Lipids and solid</td>
<td></td>
<td>Simple material handling (pumps, Pipes, valves, etc.)</td>
</tr>
<tr>
<td>Minimal risk of post-treatment contamination</td>
<td></td>
<td>High container flexibility (e.g. glass, Metal containers are possible)</td>
</tr>
<tr>
<td>The high pressure part of the system is readily available. No major development required</td>
<td></td>
<td>Maximum HP vessel volume Efficiency (&gt;90%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum vessel idle time (fast Loading/unloading, no opening/ Closing of vessel required)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>In-container</th>
<th>Bulk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex material handling</td>
<td></td>
<td>Only applicable to pumpable foods</td>
</tr>
<tr>
<td>Low volume efficiency (50-70%)</td>
<td></td>
<td>Still needs aseptic filing step, Increasing post-treatment contamination risk</td>
</tr>
<tr>
<td>Low container flexibility</td>
<td></td>
<td>Aseptic design of all higher pressure Component in contact with food required</td>
</tr>
<tr>
<td>Greater high pressure vessel idle-time (loading/unloading, fill, vent, open, close)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Examples of Existing High Pressure Vessels (Mertens and Deplace, 1993)

<table>
<thead>
<tr>
<th>Example Number</th>
<th>Maximum Working Pressure (Bar)</th>
<th>Diameter (mm)</th>
<th>Length (mm)</th>
<th>Internal Volume (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>1700</td>
<td>4000</td>
<td>9000</td>
</tr>
<tr>
<td>2</td>
<td>2000</td>
<td>1000</td>
<td>4000</td>
<td>3150</td>
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<td>1250</td>
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<tr>
<td>4</td>
<td>5500</td>
<td>600</td>
<td>2500</td>
<td>700</td>
</tr>
<tr>
<td>5</td>
<td>6900</td>
<td>250</td>
<td>750</td>
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<td>6</td>
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<td>100</td>
<td>1000</td>
<td>8.5</td>
</tr>
<tr>
<td>7</td>
<td>13800</td>
<td>90</td>
<td>550</td>
<td>3.5</td>
</tr>
</tbody>
</table>

9.0 REFERENCES

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1.0 INTRODUCTION

The collection and transportation of raw milk presents several insurmountable techno-economic problems to the dairy industry in developing countries. While efficient cooling of milk may be recommended as ideal for preservation of milk, the proposition is not always practical. The difficulties arise due to the high operational costs, frequent breakdown of equipments, erratic supply of electricity, and difficulties in timely repair of equipments in rural areas. Therefore, search of a viable alternative to mechanical refrigeration for preservation of raw milk is of prime importance. In this connection, lactoperoxidase (LP) system, that is one of the naturally occurring inhibitory systems in raw milk, has proved to offer promising results and has generated considerable interest the world over.

LP system has been recommended for milk preservation under field conditions in the tropical countries like Kenya, Sri Lanka and Pakistan as well as for preservation of cooled milk intended for cheese manufacture. The type and initial quality of milk, levels of SCN\(^-\) influence the efficacy of LP system: \(\text{H}_2\text{O}_2\) used for LP activation, temperature of storage, time of LP activation after milking and level of contamination.

2.0 ACTIVATION OF LP-SYSTEM

The enzyme lactoperoxidase is present in milk of various species in adequate quantities to permit activation of LP-system; bovine milk (3 units/ml; Bjorck et al., 1975), buffalo milk (0.16 to 0.21 units/ml; Kumar and Mathur, 1989), ewe milk (0.14 to 2.38 units/ml; Modina et al., 1989) and goat milk (0.05 to 3.55 units/ml; Zapico et al., 1990). It catalyzes the oxidation of substrates like sodium thiocyanate by hydrogen peroxide. LP mediated reactions between \(\text{H}_2\text{O}_2\) SC\(\text{N}^-\) are summarized below:

\[
\begin{align*}
\text{H}_2\text{O}_2 + \text{SCN}^- & \quad \text{LP} \quad \rightarrow \quad \text{OSC}^- + \text{H}_2\text{O} \quad \text{----- At low pH,} \\
\text{HOSCN}^- \text{ formed} & \quad \text{(Hypothiacyanite)} \\
\text{H}_2\text{O}_2 + \text{OSC}^- & \quad \rightarrow \quad \text{O}_2\text{SCN}^- + \text{H}_2\text{O} \quad \text{(Cyanosulfurous)}
\end{align*}
\]
$$\text{H}_2\text{O}_2 + \text{O}_2\text{SCN}^- \rightarrow \text{O}_3\text{SCN}^- + \text{H}_2\text{O} \quad \text{(Cyanosulfuric)}$$

End products of the intermediates are $\text{SO}_4^{2-}$, $\text{NH}_4^+$, and $\text{CO}_2$.

Conclusive evidence has been presented now that the antimicrobial effect of LP system is mediated by short lived oxyacids of $\text{SCN}^-$, i.e., $\text{OSCN}^-$ and $\text{O}_2\text{SCN}^-$. These oxyacids exert antibacterial effect by the oxidation of vital -SH groups in metabolic enzymes, e.g. hexokinase, glyceraldehyde-3-phosphate dehydrogenase, and/or depletion of reduced nicotinamide adenine nucleotide. Maximum bacteriostatic effect of LP- system was observed when equimolar amounts of $\text{SCN}^-$ and $\text{H}_2\text{O}_2$ were present as the maximum concentration of the active product of $\text{SCN}^-$ is formed at this level. However, with excess $\text{H}_2\text{O}_2$, the reaction proceeds further to completion, as given by the following equation:

$$\text{LP} \quad 4\text{H}_2\text{O}_2 + \text{SCN} \rightarrow \text{HSO}_4^- + \text{CNOH} + 3\text{H}_2\text{O} \quad \downarrow \text{H}_2\text{O}$$

At higher levels of $\text{H}_2\text{O}_2$ (10-20 micro moles/ml), the enzyme lactoperoxidase gets inactivated and the bactericidal effect is due to toxicity of $\text{H}_2\text{O}_2$ itself.

Although $\text{SCN}^-$ is present invariably in the milk of these species, depending upon feeding systems, exogenous addition of up to 21 ppm is necessary for formation of oxyacids adequate for preservative effect. Addition of $\text{H}_2\text{O}_2$ up to 30 ppm is also necessary for the enzyme-catalyzed oxidation of $\text{SCN}^-$. Higher level of $\text{SCN}^-$ and $\text{H}_2\text{O}_2$ is required for preserving milk for longer periods at higher temperature.

A number of investigations have been carried out during the last decade to evaluate the techno-economic feasibility of preserving raw milk. Bjorck (1978) demonstrated that storage period of refrigerated milk could be extended up to 5-6 days without increase in the psychrotrophic bacteria. This is especially useful in minimising the thermostable proteolytic and lipolytic enzyme that cause flavour problems in cheese (Reiter and Marshall, 1979) or reduce shelf life of UHT milk (Solanki, 1987). Studies carried out in various countries, i.e., Sri Lanka, (Harnulv and Kandasamy, 1982), Pakistan (Harnulv and Hamid 1984), India (Chakraborty et al, 1986; Gupta et al, 1986; Thakar and Dave, 1986), Egypt (Ewais et al, 1985), Poland (Zajac et al, 1983) and People's Republic of China (Wang Peng et al., 1987) have demonstrated that raw milk, without cooling, could be successfully preserved by LP-system. These studies have demonstrated that a substantial improvement of the hygienic quality of raw milk was achieved during collection and transportation after activation of LP-system at collection centres. Thus, LP-system has emerged as an attractive alternative for milk preservation especially for underdeveloped / developing
countries located in tropical zones where application of refrigeration for preservation of milk presents insurmountable techno-economic problems.

Retention of sufficient quantity of SCN- in LP- activated milk due to addition of higher levels of SCN- at the initial stage would help in enhancing the preservative effect by second dosing of H2O2 only. A residual level of 61.4 ppm SCN- was reported in 70:30 ppm (SCN-: H2O2) milk samples (Kumar and Mathur, 1989b). Chakraborty and Chaudhary (1985) observed retention of 50 ppm SCN-, when 75 ppm SCN- was added at the initial stage, and suggested addition of only H2O2 at the time of second dosing. Addition of SCN-: H2O2 at lower levels at initial stage necessitate further addition of both SCN- and H2O2 at the time of second dosing. Gupta et al. (1986) reported an extension in preservative effect of LP-system when second dosing was done after 4 h of milking. They reported a second dosing of 25:15 ppm (KSCN-: H2O2) to be optimum if LP-system was initially activated at 30:15 and 65:35 ppm (KSCN-: H2O2) in cow and buffalo milk respectively.

Milk for different species respond differently towards activation by LP-system. Cow milk is found to be more stable towards stabilisation by LP-system as compared to buffalo milk (Gupta et al., 1986). Higher concentration of SCN-: H2O2 is required to give the same preservative effect in buffalo milk as in cow milk when LP-system was utilized.

3.0 ANTIBACTERIAL MECHANISM OF LP-SYSTEM

The system has been found to be equally efficient in inhibiting gram (-) ve, catalase (+) ve organisms when H2O2 is exogenously added at low, non bactericidal concentration or is generated enzymatically. The difference in the behaviour of gram (+) ve and gram (-) ve bacteria towards LP-system could be attributed to the structure and composition of the cell wall of gram (+) ve and the outer membrane of gram (-) ve organisms, respectively. The unstable oxidation product formed due to oxidation product formed due to oxidation of SCN- in the presence of H2O2 is bactericidal to enteric pathogens including multiple antibiotic resistant strains of Escherichia coli and Klebsiella aerogenes. The Inhibitory substance may be sulphurdicyanide S (CN)2, while other investigators suggested it to be cyanosulfurous acid (HO2SCN), cyanosulfuric acid (HO3SCN) or hypothiocyanate ion (O SCN-). The enzymatic oxidation of SCN- takes place via a series of oxyacids of SCN-, of which O SCN- is the first member and the higher oxyacids are also considered bactericidal agents.

Hypothiocyanate has the capacity to oxidize free sulphhydryl groups of proteins and can cause inhibition of the enzyme hexokinase and glyceraldehyde-3-phosphate dehydrogenase. OSCN- can cause inhibition of uptake of carbohydrates, amino acids etc. and subsequently affecting the synthesis of proteins, DNA and RNA. Mode of action of LP-system on various microorganisms is either due to inhibition of bacterial respiration, inhibition of transport of glucose and valine and subsequent glycolysis, destruction of bacterial plasma membrane or inhibition of glucose metabolism.
4.0 CURRENT VIEWS OF INTERNATIONAL AGENCIES ON SAFETY OF LP-SYSTEM

An essential pre-requisite for commercial application of a preservative is that it should be convenient to administer and could be monitored. Besides this, it should be safe from toxicological point of view. The view that LP-system fulfills this criterion has been endorsed by the International Dairy Federation (IDF Bull. No. 264, 1991).

Further, regarding the toxicological aspects, the joint FAO/WHO Expert Committee on Food Additives (JECFA) has declared that the LP-system was acceptable and when used according to the guidelines provided by the Joint FAO/WHO Committee of Government Experts on the Code of Principles concerning milk and milk products, this system does not present a toxicological hazard.

5.0 ARE CONCERNS ABOUT SCN\(^-\) JUSTIFIED?

SCN\(^-\) is a normal electrolyte in many body secretions such as those of mammary glands, salivary glands and gastric mucosa. Its level in human saliva is 50 to 300 ppm, in human gastric juice 40-80 ppm. Human plasma levels are 2 to 3 ppm in non-smokers and 9 to 12 ppm in smokers where it appears as an end product of the natural detoxification process of cyanides inhaled through smoke. Besides this, because of its antihypertensive action, KSCN was used as a drug to relieve from hypertension in United States several decades ago.

Concerns have been voiced in certain forums that the dietary SCN\(^-\) may be a factor causing goiter. Finnish investigators (Vilkki et al., 1962) demonstrated that doses between 200 to 400 mg are necessary to give a thyrostatic effect. It is well documented that SCN\(^-\) is not concentrated in the thyroid gland (Meyers et al., 1978). Therefore, it is very unlikely that ingestion of recommended levels of milk containing 25 ppm of SCN\(^-\) could interfere with the iodination of thyroxine. In the event that all the SCN\(^-\) from 250 to 900 ml of milk consumed per day is absorbed, further dilution would take place in circulating blood (about 5 lit in adult with 70 kg body weight), thus contributing only about 5 ppm increment in the body fluids. Almost all of this would be excreted through the renal system in the normal course of time. Further, it has been shown that interference in the iodination of the tyrosine moieties of the thyroglobulin to form intermediates produced during the synthesis of tri-iodothyronine (T3) and tetra-iodothyronine/thyroxine T4), thyroid hormone is expected only when the SCN\(^-\) level in blood plasma exceeds 18 to 20 ppm (Bodighemert et al., 1979). However, if the iodine intake is adequate, ten times of the dose of SCN\(^-\) is required to cause hypothyroidism or disturbances in the function of thyroid gland (Gujaral et al., 1985).

5.0 WHAT DO HUMAN STUDIES INDICATE?

Dahlberg et al. (1984) conducted clinical experiments in Sweden on 37 healthy human subjects to investigate the possible effects of prolonged intake of milk with enhanced SCN\(^-\) level on thyroid function. All subjects had normal health status and no earlier incidence of goiter or thyroid dysfunction. Milk for the experiment contained 20 ppm of SCN\(^-\), and LP-system was activated by addition of 8.5 ppm of
H$_2$O$_2$. The milk was stored overnight at 4°C, pasteurized and packed in Tetra Brick, it was then stored frozen at -45°C till used.

The blood samples were analysed for hemoglobin, hemocrit (packed cell volume), thrombocytes, leucocytes and creatinine. Thyroxine, tri-iodothyronine and thyrotropic hormones were determined in serum and SCN$^-$ levels were determined in urine and serum. The increased serum SCN$^-$ levels coincided with an increased secretion in urine. The levels of serum thyroxine, tri-iodothyronine and thyrotropic hormones were all in the normal range at the beginning and no significant changes was found during the experimental period. Thus, it was concluded that a daily intake of 8 mg SCN$^-$ through 400 ml of milk containing 20 ppm of SCN$^-$ does not have any apparent effect on the thyroid function.

6.0 THE INDIAN SCENARIO

The issue related to obtaining legislative clearance for the application of LP-system for preservation of milk was brought up before the Directorate General of Health Services (Central Committee on Food Standards) in 1982. The work on basic R & D was assigned to NDRI, the work on assessment of feasibility under field conditions to the NDDB and the work on safety related issue to the ICMR. The work carried out at NDRI on the effect of LP-system indicates that the physico-chemical properties of preserved milk do not undergo any changes and microbiological quality of preserved milk is substantially superior as compared to milk preserved in the refrigeration process. Process has been developed for the formulation of tablets of KSCN and Na$_2$C$_2$O$_7$, which can be successfully employed for the activation of LP-system under field conditions. Controlled studies carried out under the supervision of NDDB clearly demonstrate the efficacy of LP-system for collection of raw milk under rural conditions and transportation to the dairy plants. Studies carried out at NIN established that Ingesting milk containing SCN$^-$ up to 50 ppm for prolonged period does not alter the iodine status or thyroid function of monkeys. The results of above-mentioned studies were examined by a group of experts nominated by the CCFS and Directorate General of Health Services in July, 1991. Most of the misapprehensions that were expressed inadvertently relate to the literature reports on the long discontinued practice of treating hypertension through oral administration of SCN$^-$ to raise its level to 18-20 ppm in serum.

Closer perusal of the relevant literature reveals that accumulative effects of SCN$^-$ would be observed only when ingestion levels exceed the renal excretion capabilities of human systems under normal physiological conditions. It may thus be estimated that ingestion of up to 800 ml of milk (containing 25 ppm of SCN$^-$) in communities that favour milk-drinking habit would not lead to accumulation of SCN$^-$. While considering toxicological related issues adequate discretion should be made to distinguish the biological effects arising from 200 to 600 mg enteric doses of SCN$^-$ for the treatment of hypertension and preservation of milk by LP - system. Thus, misapprehensions regarding accumulative effects producing toxic manifestation in thyroid function, drowsiness and CNS$^-$ combination with blood to produce cyanomethaenoglobin could be logically allayed, which are observed when serum SCN$^-$ levels exceeds 12 mg/100 cc (Stecher et al., 1960).
7.0 CONCLUSION

LP- system is one of the nature’s way of providing the protection to the mammalian species against a variety of infections through saliva, tears and milk. Recent R & D work had demonstrated the possibility of harnessing the innate antimicrobial factors present in milk for preservation. LP-system has emerged as an attractive techno-economic alternative to refrigeration for preservation of milk under tropical climatic situations. There is a need to reexamine the safety related issues by judiciously distinguishing the literature reports on the metabolic fate of very high concentrations of SCN⁻ (from intake of about 600 mg as an enteric tablet) in the blood serum for treatment of hypertension. Since these toxic effects are not observed at lower levels of SCN⁻ ingestion resulting from intake of preserved milk, misapprehensions on the safety of LP- system may be allayed.

8.0 REFERENCES


1.0 INTRODUCTION

Microencapsulation is a technique by which liquid droplets or solid particles are coated with a thin film of protective materials. The droplets or particles are called “Core” material and thin film coating is called “Wall” material. The film or wall material protects the “Core” material against deterioration, limits evaporation of volatile core (in case of flavours) and also facilitates the release of core under predetermined conditions. Fats and oils, flavours and aroma compounds, oleoresins, vitamins, minerals, colorants and enzymes have been successfully microencapsulated.

Spray drying is most common microencapsulation technique in foods industry. Spray drying technique for producing “encapsulated” flavouring was discovered by A Boake Roberts in 1937, when he accidentally added acetone to tomato puree which helped him to maintain colour and flavour of tomato powder during spray drying. Subsequently, spray drying has become the most important commercial process for making dry flavourings. Vitamins, minerals, colorants, fat and oil, flavour, aroma compounds, oleoresins, enzymes have been microencapsulated, using spray drying technique (Dziezak, 1988, Jackson and Lee, 1991, Shahidi and Han, 1993; Xiang, et al., 1997a).

Re-MI (1998) presented a review on microencapsulation by spray drying with special emphasis on the microencapsulation of volatile materials. Microencapsulation by spray drying offers advantage over conventional microencapsulation technique (i.e. coacervation, fat or wax encapsulation, plating or adsorption, inclusion in cyclodextrins, etc.) by producing microcapsules via relatively simple, continuous process. The spray-drying equipment used for the production of dry flavourings such as cheese flavour, butter flavour etc. is essentially the same as is used for the production of dry milk.

Spray drying has been used to improve the stability of carotenoids in carrot pulp and paprika oleoresins. Maltodextrins and gum arabic was used as microencapsulating agents (Leach, et al., 1998). Microencapsulation of capsicum oleoresin in a gum composed of carrageenan and maltodextrin at a ration of 0.5 - 3.5 : 9.5 - 7.0 was attempted. Microcapsules were formed by homogenization, emulsification and spray drying. The product contained 92.6% capsicum oleoresin with recovery rate of 91.5% (Xiang, et al., 1997 b).

Lin et al., (1995b) microencapsulated ferrous sulphate by low temperature spray drying using glycerol monostearate (GMS) as well material and added to whole milk powder which have more oxidative stability as compared to free ferrous sulphate.
2.0 COMMON ENCAPSULATING (WALL) MATERIALS

The most important step in encapsulation of any “Core” material by spray drying is the selection of suitable “Wall” material which should form a continuous thin film and prevent deterioration and evaporation of the core material. The material should be low in cost; bland in taste and stable during storage.

The functionality profile of wall material includes high solubility, effective emulsification, low viscosity at high level of solids (<500 cps at >45% solids), low hydroscopicity, easy release of “Core” material and efficient drying properties. The material used for flavours and other food material (such as anhydrous fat, natural cheese solids, etc.) are; gum arabic, hydrolyzed starches or maltodextrins, modified starches and whey proteins concentrates or isolates. In addition, a number of commercial preparations such as national® 46 (NAT46); Encapsul 855 (ENC855) from National Starch and Chemical Corp. Bridge Water, New Jersey USA and Amiogum® from American Maize Product, USA having one or more common wall agents are in the market. Sodium alginate and Gelatin of food grade quality have also been reported as wall material (Rosenberg, and Young 1993). Lee et al., (1997) investigated the viscosity and spray drying properties of several polysaccharides (gum arabic, maltodextrin, dextran and mixtures of gum arabic and maltodextrin) to know their potential as wall materials for microencapsulation and also presented SEM for some selected polysaccharides after spray drying. The encapsulation properties of several commercial food proteins and gum arabic have been evaluated by conventional analytical procedures and dynamic headspace analysis (DHA) (Kim and Morr, 1996).

2.1 Gum arabic (acacia)

It is one of the oldest and traditional wall material or carrier used in spray drying. It is a natural exudates from the trunk and branches of leguminous plants of the family Acacia (Thevenet, 1988), grown in Sudan, Senegal, Mali and Nigeria. Although this is one of the most preferred wall material (Noor et al. 1996), the consumers use alternative carriers for dry flavourings and other core materials due to its low production (300 gm/plant/year) and high cost. Kim and Morr (1996) used DHA to determine the rate of release of volatiles from the spray-dried, microencapsulated orange oil emulsion particles and their studies revealed that gum arabic microencapsulated particles had the highest volatile release rate and soya protein isolate-encapsulated particles the lowest release rate. The DHA studies conclusively pointed out that gum arabic was not the best wall material for encapsulating orange oil.

2.2 Modified starches

The chemically modified starches most closely reproduce the functional properties of gum arabic. The natural starches virtually have no emulsifying property. Esterification with cyclic dicarboxylic and anhydrides impart emulsifying power to partially hydrolysed starches. This technique is practised on commercial scale to tailor made the wall/carrier material. The modified starches are reported to be superior to gum acacia in emulsifying properties and in retention of volatile flavours during spray drying (Trubiano and Lacourse 1988). Aburto et al. (1998)
obtained best microencapsulation of orange essential oil with the mix containing 10% modified starch and 36% maltodextrin. But modified starches are not considered as natural food component.

2.3 Hydrolysed starches

This is one of the most common and cheapest wall/carrier materials. The hydrolysed starches are available in dextrose equivalent (DE) range from 2 to 36.5 and offer good protection against oxidation. These are low in viscosity at high total solid contents. However, they lack in emulsifying properties. It is therefore, used along with gum acacia or other emulsifying agents like protein (Noor et al., 1996), whey protein concentrate and whey protein isolates (Young et al., 1993a; Sheu and Rosenberg, 1995). Maltodextrins and low dextrose-equivalent (DE) corn syrup solids (CSS) when dried manifest matrix forming properties important in wall system (Kenyon and Anderson, 1988). However, the surface active characteristics of such carbohydrates and the low viscosity of their solutions do not promote emulsification of oil like materials. A stable emulsion of fine droplets of core material in the wall solution is critical in micro-encapsulation. Therefore, when maltodextrines or CSS are used as constituents it is necessary to incorporate other wall materials such as gelatin, sodium caseinate, whey proteins, lecithin, etc. for improving emulsifying characteristics (Lin, et al., 1995b). Retention of volatile flavours compounds decreased as maltodextrins DE increased (Bans and Reineccius, 1981).

High DE maltodextrin protected encapsulated orange peel oil against oxidation. (Anandaraman and Reineccius, 1986) suggesting importance of DE to the functionality of wall system. Mixture of gum arabic and maltodextrin was reported effective in micro-encapsulation of cardamom oil using spray drier (Sankarikutty et al., 1988). They used Buchi 190 mini spray drier equipped with a nozzle of 0.5 mm diameter. It had a chamber with inside dimension as 44 cm high and 10.5 cm diameter. The viscosity of infeed was 98±5 cps (30°C). The water evaporation rate of spray drier was 0.25 kg/hr at inlet air temperature of 155±5°C and exit air temperature of 100±5°C with 6 Kg/cm2 atomization pressure.

A technique for microencapsulation of perilla oil was investigated. Soy protein isolate and maltodextrin (encapsulating agents) and water were mixed, heated to 60°C and agitated for 30 min before addition of perilla oil and agitation for a further 30 min and then spray dried (200°C and 80-90°C). Encapsulation efficiency was 84.6%. Linolenic acid content of encapsulated perilla oil varied slightly from that of free oil (Cui and Ding, 1997).

2.4 Whey proteins

Starch and related products lack emulsification properties and are not used as wall materials in the absence of surface active wall constituents (Lin, et al., 1995b). Whey proteins owing to their structure manifest functional properties that are desired in a good wall material for an effective microencapsulation of anhydrous milk fat (Rosenberg and Young, 1993 and Young et al., 1993b). Whey proteins in combination with maltodextrins and corn syrup solids have been reported to be the effective encapsulation material during spray drying (Young et al. 1993a; Lin, et al.,
Mixture of whey proteins with natural or modified carbohydrate has been used for microencapsulation of anhydrous milk fat. In such systems, whey protein served as emulsifying or film forming agents while carbohydrates acted as matrix-forming material (Young, et al., 1993b). Mixture of whey protein and maltodextrins appear to provide functionality profile for successful microencapsulation of volatile materials. The wall system consisting of whey protein isolates and high DE maltodextrins were effectively used for microencapsulation of volatiles by Sheu and Rosenberg, (1995).

3.0 SPRAY DRYING

Spray drying is one of the commercial process which is widely used in large scale production of encapsulated flavours and volatiles (Deis, 1997). Most of the processing details about production of food, fruit, dairy and synthetic flavours are closely guarded secret. The information available in the literature is very scanty. The available information is based on model systems for testing and standardising the use of particular carrier system for known volatile, liquid or solid core materials. Tuley (1996) discussed the microencapsulation of food ingredient in detail which covered aspects like reducing loss of flavour compounds during processing through encapsulation technology. The flavour microcapsules for spray drying are formed with the help of wall and core material. The wall material is dissolved or dispersed in water in concentration which is, largely, dependent upon the wall material. The flavour or core material is then emulsified in the solution of wall material using suitable mechanical means (high speed mixing, homogenization etc.). A stable emulsion of the fine droplets of core material in wall solution is critical for microencapsulation (Kenyon and Anderson, 1988). The stabilized emulsion is pumped through atomizer (nozzle or disc type) under predetermined conditions of pressure or speed of atomizer; inlet and outlet air temperature; infeed temperature and infeed rate etc., in the spray drier where drying takes place. The design of spray drier chamber may play a role in better flavour retention and stability of core material. The process of microencapsulation using spray drier is a continuous process and therefore, can take care large production rates.

4.0 SHELF-LIFE OF ENCAPSULATED FLAVOURS/CORES

Retention of flavour components during spray drying is the first concern. The second most important concern may be the stability of retained flavour during storage at predetermined conditions. The shelf-life of flavour in most flavours oils (citrus oils) is typically related to its oxidative stability. The major determinant of oxidative stability is the selection of the carrier (Subramaniam, 1984) and the particle size. Chang, et al., (1988) found that the powder produced at intermediate wheel speed had 53.21 micron average particle size and was reported to be the most stable to oxidation. They hypothesized that stability should increase with increasing particle size; however, surface imperfections increase with particle size, and at some point the surface imperfections leave the oil susceptible to oxidation and thus decrease stability. They therefore concluded that there is an optimum particle size for high stability.
Water activity is another factor which determine the stability of spray dried powders. It is well documented in the literature that lipid oxidation is minimum at the monolayer (water activity circa 0.2) increases on either side of monolayer (Kinsella and Fox, 1978). Anker and Reineccius (1988) found that shelf life of orange peel oil evaporated in gum acacia increased with water activity within the range, 0.0 to 0.536. The range of water activity for flavour stability is depended on the type of wall/carrier material used. It is therefore, clear now that microencapsulated flavours in dry form may have high moisture content 5-8% than the traditional dry powders (2-5% moisture) for improved oxidative stability.

5.0 CONCLUSION

Microencapsulation of core materials (flavours and aroma compounds, enzymes, vitamins, mineral, colorant etc.) using spray drier is vitaminised as a commercial process for their large scale production. The list of a carrier or wall materials is now extended from gum acacia to starches, modified starches, maltodextrin, whey proteins, soya protein and so on. The spray drying process has number of process variables such as design; type of atomizer; speed or pressure of atomization; infed temperature, pressure and rate; inlet and outlet air temperature; single and multistage drying etc., which can be manipulated to optimize the retention of “Core’ material for a given blend of ”Wall” material. It is possible to develop products like cheese flavours concentrates, dairy flavours, butter milk powder, yoghurt powder, vitamins and minerals concentrates employing spray drying process for dry mixing in number of formulated and simulated food requiring dairy flavour profiles. The un-utilized capacity of spray drier of Indian Food Industry may be used profitability even in the lean-season for production of non-dairy microencapsulated flavours such as natural fruit flavours etc.

6.0 REFERENCES

1.0 INTRODUCTION

In the range of membrane processes, Microfiltration (MF) fits between the process of ultrafiltration (UF) - widely used for separation of proteins from the low molecular weight solutes - and the traditional filtration using filters of varying porosity. The size range of particles that can be separated by an MF process varies from below 0.1 μm to about 5μm and these could include colloidal and globular particles such as casein micelles, whey protein aggregates and milk fat globules, as well as unicellular materials of biological origin such as somatic cells, bacteria and other microorganisms (Jost and Jelen, 1997).

The development of new ceramic membranes has been a major breakthrough in making MF an acceptable industrial separation technology in the dairy and food industry. The ceramic membranes with a highly permeable support and a multichannel geometry as also high stability to heat, acid and alkali, have opened up novel applications of MF technology. MF is a pressure driven process operating at transmembrane pressures of less than 1 bar. A wide range of MF membranes is now available with pore sizes varying from 0.1 to 1.4 μm. The major dairy industry applications of MF have been i) removal of bacteria ii) whey defatting iii) micellar casein enrichment of cheese milk iv) fractionation of milk proteins (Maubois, 1997).

Various techniques have been developed to improve the bacteriological quality of milk without affecting the flavour and nutritional value of the milk. One of the most popular among these is pasteurization. However, pasteurization is not very effective in decreasing the spore count of the milk. UHT processing, high pressure treatment, ultrasonic treatment, bactofugation and pulsed high energy treatment etc. are newer of techniques being used for removal of bacteria but these have met with limited success (Hulsen, 1999). UHT milk is criticized for its cooked flavour and brown colour while bactofugation is energy demanding and the spore-reducing effect is rather limited.

2.0 MICROFILTRATION OF SKIM MILK TO REMOVE BACTERIA

2.1 Equipment related developments

Microfiltration, as a process for bacteria removal from milk, is drawing the attention of engineers and scientists all over the world. With the development of inorganic (ceramic) membranes with large pore diameters of more than 1 μm,
exceptionally high permeation rates in the processing of milk can be obtained. Permeate fluxes as high as 1000 LMH have been reported with milk and the system can be operated for several hours at a stretch without any significant change in the permeate flux (Pafylia et al., 1996). A major limitation of the MF process has been the tendency of the colloidal aggregates to get trapped in the membrane pores followed by a cake formation on the surface of the membrane leading to the creation of a new dynamic membrane layer. This layer changes the overall filtration characteristics and the rejection properties are no longer governed by the initial pore size of the membrane (Daufin and Merin, 1995). The partial or complete blocking of pores has been the reason for shorter MF operational times, and also for reduced permeability and increased rejection. In order to limit fouling, MF must operate at high cross flow velocity with increased shear rate on the membrane surface (Maubois et al., 1987). Such high flow velocities cause an increase in the transmembrane pressure (TMP) and pressure drop ($P_{in} - P_{out}$) along the filter module and this is the most critical parameter of flux decline in MF of milk (Malmberg and Holm, 1988). Experience shows that a low TMP gives a much better performance, but in the case of conventional MF, a low TMP is seen only at the outlet, that is, on a very small part of the membrane area. In order to solve this problem of pressure drop along the length of the membrane, Tetra Pak has proposed a Uniform Transmembrane Pressure (UTP) mode of operation in which a part of the permeate is pumped back to the shell of the membrane unit causing a back pressure and a consequent decrease in effective TMP. By controlling the amount of permeate being pumped back into the shell, the TMP can be suitably controlled (Cheryan, 1998).

6.0 The process

Studies have been carried out in various laboratories in Europe and US to study the effectiveness of MF in UTP mode for the removal of microorganisms. The difference existing in size distribution between casein micelles and the microorganisms most frequently encountered in milk has led to the development of ‘Bactocatch’ process by the Tetra Laval group (Larsen, 1996). In this process skim milk is circulated under pressure along a ceramic MF membrane (pore size 1.4 μm) at a temperature between 20-55°C. The average TMP is $0.55 \times 10^5$ Pa. Transmission rates of total solids, protein, fat and cholesterol are respectively 99.5, 99, 63 and 85% when concentration factor is equal to 20. The system is capable of removing 99.5% of all the bacteria in the skim milk. The bacteria concentrate is mixed with the cream which is used for standardizing the cheese milk and this mixture is heated to 130°C for 4 s in the High Temperature Treatment (HTT) equipment. Finally, the permeate and the cream/retentate mixture are re-mixed and when the milk reaches the renneting temperature it is led into the cheese vats (Kessler, 1997). The number of anaerobic spores in cheese milk are reduced significantly without sacrificing the properties of coagulation (Samuelsson et al., 1997).

The processing time with the MF for pasteurised milk (Tetra Therm ESL) represents the combination of ‘Bactocatch’ with a legal pasteuriser. The raw milk is preheated, separated and the skim milk is subsequently microfiltered, separated into a bacteria-poor skim milk (permeate) and a bacteria rich skim milk (retentate). The retentate is mixed with a standardized quantity of cream and this mix is heat treated at 120-130°C for 2-4 s. The high temperature treated part is then mixed with the
permeate and the final mixture is homogenized, pasteurised and stored before packaging. The main advantages of this process are the improvement of the bacteriological quality and the extension of shelf life of the pasteurised milk while maintaining, the characteristic fresh taste. Legally, it is considered as a raw milk because its phosphatase test leads to a positive result in spite of the heat treatments applied to its components being more intense than the legal requirements. The sensory qualities of fluid milk resulting from MF treatment are highly appreciated by consumers. Somatic cells, which can induce detectable defects in dairy products made from milk having a content higher than $4 \times 10^5$ SCC/ml, are absent in the MF treated milk. This leads to increased technical advantages and hygienic safety in dairy processing. A small decrease in the TS content of the microfiltered milk (i.e. permeate) makes it more heat stable. The change in TS is due to partial fractionation of casein micelles because there is little difference in the whey protein content of permeate and retentate on MF of skim milk (Steele et al., 1998).

3.0 POTENTIAL IN TROPICAL COUNTRIES

Microfiltration for the removal of bacteria from milk has greater potential in tropical and sub-tropical countries. In such countries, refrigeration facilities are inadequate, high ambient temperature favours the growth of microorganisms, and the environment, poor physiological condition of the cattle, unhygienic conditions at the time of milking the cattle or processing of milk, manual handling of milk or improper cleaning of equipment and pipelines contribute to a large extent to the bacteria in the milk, many of them pathogens. High initial count milk may behave differently in terms of bacteria and spore removal on MF. Studies have been carried out on MF of skim milk for extension of shelf life of milk at our institute using MFS-1 unit of the Tetra Pak Filtration Systems equipped with 1.4 µm-ceramic membranes.

A permeate flow rate of up to 200 l/h (833 l/m²/h flux) resulted in satisfactory operation since the transmembrane pressure remained below 1 bar and fouling was negligible. The SNF content of the permeate was found to decrease by only 0.2 % due to slight retention of casein micelles. The efficiency of MF in decreasing the microbial load of milk was nearly 99.99% for bacterial cells and 99% for the spores. The heat stability of milk remained unaltered after the MF process. The shelf life of the microfiltered milk and that of the pasteurised-microfiltered milk was found to be more than a month as compared to four days for raw milk and fourteen days for the pasteurized milk when stored at 4-6°C. Microfiltered milk, because of its low bacterial and spore counts, can be considered to be ideally suited for subjecting to UHT treatment particularly under Indian conditions. The extent of heat treatment employed for the UHT processing of microfiltered milk can be reduced by lowering the time-temperature combination and this may result in improved quality UHT milk.

4.0 FUTURE PROSPECTS AND CONCERNS

Extended Shelf Life (ESL) milk products wherein MF has been used as a pretreatment step, are making inroads into more and more markets these days (Koel, 2000). Because ESL processing offers gentler product treatment than conventional long life systems the products are said to taste better. Some analysts predict a huge volume growth in ESL liquid dairy products. They forecast that in USA, UK, Germany and Japan, sales of these items will grow from 1.1 billion litres to 8.1 billion litres by 2003, a jump from 3% to 22%.
Most bacteria found in raw milk are non-pathogenic, though small amounts of pathogenic bacteria such as *Listeria* and *Salmonella* may also be present. These bacteria which are normally killed by heat treatment, do not produce foul odours or taste. The ESL treatment could reduce non-pathogenic bacteria to a point where harmful ones, if not destroyed, could not only remain undetected, but flourish because of the resultant lack in competition for nutrients from non-pathogenic bacteria. Heating of ESL milk therefore, becomes essential though it can be carried out at a lower temperature and for a shorter time than the ultra heat treated products.

Strict heating and hygienic standards must be adhered to at every step of ESL production and temperatures of 7°C or less must be ensured at every stage of distribution. Another concern is that of labeling. The labeling should be a consumer oriented name and not a detailed process description e.g. ‘Pasteurised Filtered Milk’. A company marketing milk which has been microfiltered before heat treatment in UK is using the slogan "The best tasting fresh milk" for their product and has met with considerable success.

5.0 CONCLUSION

Microfiltration with large pore size membranes is a relatively new technology and has gained importance after the development of ceramic membranes, which made it possible to have high fluxes even with milk. Application of the uniform transmembrane pressure concept during MF keeps the fouling to an insignificant level. A significant decrease in the bacterial cell and spore count increases the shelf life of the milk and UHT processing if combined with MF can provide long life milk with improved quality and at lower energy costs.

6.0 REFERENCES


1.0 INTRODUCTION

Osmosis as a pre-treatment since long has been used in the processing and preservation of certain food products such as salting & curing of meat and fish products, candying and semi-candying of fruits and vegetables. However, osmosis differ from this these traditional soaking processes as here significance water removal takes place (40-70 % water) with limited and controlled solute gain.

Research on osmotic dehydration, as also named dewatering and impregnation soaking process (DIS) process was pioneered in 1966 by James D. Ponting. Since then a number of research work has been published throughout the world covering various aspects of osmotic dehydration.

Osmotic dehydration has mainly been applied to fruits and vegetables, however in recent years meat and fish and non-food materials like agar gel has also been studied. Presence of active tissue systems in fruits and vegetables even after harvesting make it an ideal object for osmotic dehydration.

2.0 MECHANISM OF OSMOTIC DEHYDRATION

In osmotic dehydration process, a solid product of high moisture content is immersed in a concentrated solution (mainly of sugar or salt), which initiates three types of counter-current mass transfer.

- Water outflow from the product to the surroundings solution as a result of osmosis through a semi-permeable membrane.
- A solute transfer, from the solution to the product.
- A leaching out of the water-soluble component along with water from the product to the solution. The last two mass transfers occur mainly because of diffusion.

This counter current mass flow is due to the water and solute activity gradients across the cell’s membrane. This process continues till the osmotic potential on two processes reaches an equilibrium.

In an ideal osmotic solution a semi-permeable membrane would be permeated by the solvent molecules but not by the solute molecules. In fruits and vegetables, the cell wall membranes are living biological units and selective
permeable, which can stretch and expand under the influence of growth and turgor pressure generated inside the cells. These cellular membranes, which are composed mainly of parenchymatous cells, freely allow the solvent molecules to pass through, but they also allow, to a lesser degree, the passage at some of the solute molecules. (Torreggiani, 1993) Such membranes should be called as differentially permeable, rather than semi-permeable.

Fig.1 Diagrammatic Presentation of Osmotic Dehydration

However, the need of an intact cellular membrane is no more a pre-condition for achieving high water loss and low sugar gain, as similar effect was observed with a model food gel with no membrane. Such findings provide us possible explanations that there are certain other mechanisms of dewatering and impregnation because many times processors have to work with raw materials having wide variations in their physic-chemical properties. Thus it is now clear that osmotic dehydration can be applied to any food structure, be of plant origin, or animal derived or of a gel type.

In any type of food product, many mechanisms can be acting at the same time, the relative contribution of which depend upon product nature and operating conditions: osmosis, diffusion, flux interactions and shrinkage, that may results in 40-50% decrease in initial volume.

Recent studies of Vacuum Osmotic Dehydration (VOD) have shown that the action of capillary pressure significantly intensified water removal, particularly in case of product with high porosity (Hough et.al. 1993).

Compared to conventional drying process, two-fold transformation of the product is achieved by affecting both a dewatering and a formulation effect. However, this alone is not able to produce a self-stable product and complementary processing step (s), such as drying, freezing, pasteurization, canning, frying and/or the addition of chemical preservatives is essential.

The major characteristics of all type of food products subjected to osmotic dehydration, is the formation and retention of a superficial concentrated solute layer. This layer is found to be located within the 2-3 mm depth of the product, whereas water removal takes place from deep inside the product (Raoult-Wack, 1994). This superficial layer has a major effect on the control of mass transfer during osmotic
dehydration, favouring water loss, limiting solute impregnation and reducing the loss of water-soluble solutes. Presence of this solute layer may influence the product behaviour during complementary processing. However, this behaviour is not yet fully understood.

3.0 PROCESSING VARIABLES

Mass transfer i.e. moisture removal and solid gain, process has been found to be dependent on both product characteristics and operating variables. All these variables have been thoroughly researched and reviewed by number of workers. Some of the important parameters are discussed here in brief.

3.1 Nature of the commodity

Rate of mass transfer is mainly governed by the raw material characteristics. The great variability among the different fruit is mostly related to tissue compactness (Giangiacomo, 1982), intracellular spaces, presence of gases, ratio between the different pectic fractions, gelification level of pectin, initial insoluble and soluble solid content and enzymatic activity of the fruit. (Lenart and Flink, 1984. Forni et al. 1986.

3.2 Pre-treatments

Food products are invariably subjected to certain pre-treatments to obtain a better quality product like blanching, sulphiting. All such pre-treatments modify the tissue permeability and it mostly manifested in increase tissue permeability and decrease in selectively. It favours the solid gain compared to water loss because impregnation phenomenon are enhanced (Karel; 1995; Islam and Flink, 1982). Initial workers advocated the use of chemicals rather than blanching to control the undesirable changes in food product in view of its effect on cell membrane integrity & permeability (Ponting, 1973). Similarly frozen fruits and vegetables are not suitable for osmodehydration process.

3.3 Osmotic agent

Osmotic agent must have lower water activity, good solubility, constant concentration during processing, and it should be cheap. However, non-toxicity, inertness to food constituent and good sensory attributes is other added attraction, while selecting any osmotic agent. These are number of compounds available, satisfying above mentioned criteria, like, sucrose, glucose syrups, invert sugar, corn syrups, honey, and humectants such as sorbitol and glycerol.

The kind of sugar utilized strongly affects the kinetics of water removal, and by increasing the molecular weight of osmotic substance, larger water removal could be achieved with little uptake of solutes. (Contreras and Smyrl, 1981). Low molecular weight substances (glucose, fructose, sorbitol etc.) Favours the sugar uptake because of the high velocity of penetration of the molecular so that solid enrichment instead of dehydration is the main effect of the process.

Sodium chloride (NaCl) is an excellent osmotic agent for vegetables and other animal derived products, but its use with fruits is restricted because of alteration in
taste and bleaching of colour. Addition of NaCl to osmotic solution increased the driving force for drying owing to the a_w lowering capacity of salt. Synergistic effects between sugar and salt have also been observed (Lenart and Flink, 1984b). On the basis of above discussions the use of blends comprising two or more solutes seems to be an attractive alternative. However, the optimisation of levels of solutes through experiments is advisable before using them on larger scale.

3.4 Temperature

Processing temperature influenced not only the rate of osmosis, but also the quality of finished product. The rate of mass exchange increased with temperature but above 45°C enzymatic browning and flavour deterioration begins to take place. Some of the workers reported upper limit to be 60°C because above this temperature, modification in tissue characteristics leads to impregnation phenomena. High temperature Short-time treatments, at 80-85°C for 1-3 min, combine the osmotic effect with enzymatic inactivation by blanching (Lerici et al., 1986).

Many researchers reported acceleration of water loss without modification of sugar gain when temperature is increased. The possible explanation for such behaviour could be diffusional differences between water and solute as related to their different molar masses.

Besides these variables, concentration of syrup, sample to syrup ratio, agitation, specific surface area of the food product, time of processing and pressure of the medium also affect the mass exchange.

Use of high concentration solutions and reducing the size of food product to an optimum level favour mass reduction. Beyond a certain concentration water loss overtake solids gain.

4.0 MODELLING OF MASS TRANSFER

One of the biggest obstacles in the commercialisation of osmotic dehydration is the engineering problem related to the great volume of concentrated sugar solution and unavailability of equipment for continuous operations. Mathematical modelling of mechanisms involved in simultaneous interacting counter-current flows is still lacking. Some of the models developed by investigators are discussed here.

4.1 Diffusional approach

It is based on the assumption that mass transfer occurs in an unsteady state and follows the Fick’s second law. Fick’s second law provides a linear relationship between the flux of a component and the concentration gradient of that component. The estimation of diffusion co-efficient in this method serves as suitable index for estimating waters loss/solid gain in the product.

4.2 Rate approach

This approach involves application of rate equations (Foist order Arhenious Kinetics) to model the water loss during process of OD. It establishes a relationship
between loss of water with time, temperature, concentration, and/or other process variables. Once the model is developed with respect to a particular food and specific process condition, it could be scaled up for industrial application, Magee et al., (1983) developed a model that indicates proportional relationships between concentration parameters and the square root of time. In many models, simultaneous water and solute transfer is resolved to a simple transfer of water or solute, which resolved to a simple transfer of water or solute, which is insufficient as far as technological development of the process is concerned.

4.3 Mass balance approach

Recently developed these models are the extension of rate approach models. The models studied by Azura et al., (1991) was successfully tested to predict water loss and solute gain for various products.

4.4 Compartmental model

The ‘bicompartmental’ developed by Raoult-Wack et al., (1991) Consider formation of solute layer. Formation of this solute rich layer below the surface of product results in the formation of two compartments and two fold mass transfer occur. Model generates informations that are relevant not only for predicting mass transfer but also for optimisation of product quality and energy management.

Certain models have been modelled by the principle of irreversible thermodynamics (Toupin et al., 1989; Panagitou et al., 1998) and diffusion of components has been attributed to the trans membrane transport. These models took into account the cell membrane characteristics such as cell volume change, tissue shrinkage, internal volumetric rearrangement and diffusion of non-permeating and permeating species. These models are more complex and quite successful on a macroscopic scale.

All the models discussed above concerned as carried out at normal pressure. However, OD under vacuum has recently been developed and total mass transfer rate was described by a combination of Fickian diffusion and Vacuum capillary flow.

5.0 EFFECT ON PRODUCT QUALITY

The osmotic dehydration has been proved as an effective pre-treatment to improve the nutritional, organoleptic and functional characteristics of the food products. Osmotic treatment enhanced the acceptability of the product by modifying the acid to sugar ratio, particularly suitable for highly acidic fruits. Another important aspect is protective effect of osmotic dehydration on its natural tissue structure during subsequent processing such drying, freezing and freeze drying, by limiting collapse and cellular disruption. (Bolin and Huxsoll, 1993). Since the process operates at relatively lower temperature, it does not alter the natural cell structure in biological systems. Combination of osmotic treatment with other processing techniques like vacuum drying, high temperature fluidized bed drying (HTFB) resulted in products with soft and raisin-like texture. Similarly puffy products with honeycomb-like texture can be obtained at a cost comparatively less than freeze-drying.
The sugar uptake owing to the protective action of the saccharides, limit or avoid the use of SO\textsubscript{2} (Maltini \textit{et al.}, 1991) and increase the stability of pigments during processing and subsequent storage. Selection of suitable osmotic agent and controlled processing may help in achieving the a\textsubscript{w}, where the rate of most of the microbial and chemical reactions are minimum. Levels of heat sensitive vitamins are preserved in osmotically treated commodities, as it does not involve any phase change.

Flavour of osmotically dehydrated products rated superior than conventional processed ones, because of the protective action of sugar and lower temperature of processing.

6.0 INDUSTRIAL APPLICATION

Osmotic dehydration as a process on commercial scale is limited to certain part of the world. It produces products of varying type like semi-dried, dried, or preserves, suitable for consumption as snack food or as ingredient in other food products. Moreover, the process has been used as pre-treatment before drying, freezing and other complementary processing to obtain a stable product. Osmotic treatment not only saves energy but also impart desirable sensory nutritional and functional attributes.

Recent developments in the field of mass-transfer control have re-enforced the industrial potential of osmotic dehydration, which can be used as dewatering process without any significant solute gain or as a formulation process or both together to obtain various kind of products; minimally processed, self-stable products or intermediate moisture food. In countries like India, where poor handling, transportation and storage facilities resulted in substantial loss of fresh produce, osmotic dehydration as a preceding processing before sun drying and or conventional drying, may be utilized for value addition at a relatively lower cost, in remote areas. It is particularly relevant to UP hills, and North-Eastern States;

7.0 OTHER RELATED PROCESSES

Osmotic dehydration makes it possible, not only to improve but also to radically modify conventional processes. Some of the processes developed recently and based on Osmotic principle are as follows:

7.1 Production of aroma concentrate

A new process for the production of fruits and vegetables aromatic concentrate has been designed. These concentrates are produced by an osmotic pre-concentration stage of fruit pieces, which are then crushed and refined. Frozen or pasteurized aroma concentrate may be used as natural ingredient.

7.2 Direct osmotic concentration process (DOC)

It is a modified membrane processing and has been develop for the liquid foods (Wong & Winges, 1999) In DOC a concentrated solution with a high osmotic
pressure is circulated on one side of the membrane and the dilute solution to be concentrated on other. Water moves across the semi-permeable membrane due to osmosis and the dilute solution becomes more concentrated. It differs from RO as in DOC the Osmotic pressure is the driving force rather than hydraulic pressure DOC can concentrate fruit juices to 45% soluble solids and membrane fouling is considered to be less of a problem.

8.0 PROSPECTS IN DAIRY INDUSTRY

Though the dairy products don’t possess semi-permeable membrane, but as the necessity of a semi-permeable membrane for osmotic dehydration seems to be no more of a pre-condition. There is lot of scope for its application in dairy products for processing as well as quality improvement. Continuous production of indigenous dairy products like gulabjamun, rasgolla, chhanna based sweets, require an in-depth understanding of diffusion characteristics of sugar syrup into these products and effect of process variables on the process and product characteristics. Partial dehydration of coagulated dairy products and then subsequent drying has been encouraging and through process modification it is now possible to develop new food product at relatively cheaper cost. Process improvement in salting/brining of cheeses could be achieved through better understanding of mass transfer process in these products.

Furthermore, dairy by-product whey with slight modification can be a used as osmotic agent. This has to be investigated thoroughly.

9.0 LIMITATIONS

However, following problems, despite significant achievements, has hampered the implementation of osmotic dehydration on industrial scale,

- Difference in density between solid phase (product) and liquid phase (solution) prevent effective mass transfer.
- Compositional changes in osmotic solution during processing. Re-concentration can be achieved by adding dried component in binary solutions, but in mixed solutions, deviation from normal ratio, is difficult to ascertain. Such syrups to other processing time may be one recycling of one possible way for their utilization.

10.0 CONCLUSION

Considerable efforts have been made over the past decade to improve understanding of mass transfer in OD. However, the main advances presented above need to be furthered in many areas: modelling, equipment, and process control. product quality and optimization of combined process. There is still a lot of scope to carry put further investigations in following areas before industrialization of the process.

- Management of concentrated solution volumes.
- Microbiological validation
• Mass transfer on the product-solution interface
• Stability impregnated products
• Application in newer type of food products

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1.0 INTRODUCTION

Some food products, for example, certain varieties of cheeses, wine and whiskey, hams, etc. require extended aging/storage under controlled conditions to undergo desired changes for developing characteristics flavours. But, not all foods and beverage products increase in sensory quality with storage or holding time. Problems related to storage stability, particularly under tropical conditions, are common to food industry. To maximize product keeping quality, producers must know and be able to control the conditions under which their products are produced, warehoused, distributed and displayed. Storage studies to predict shelf life are an essential part of every product development, improvement or maintenance programme. A completely new set of stability characteristics may be generated each time a product is modified. It is unwise to place a product in market channels without prior knowledge of its shelf life. Waiting for consumer's decision takes time, is costly and may affect the sales. Pre-testing to determine shelf life is therefore critical.

2.0 SHELF LIFE AND CHANGES DURING STORAGE

The institute of Food Technologists defined shelf life of a product as ‘the period between manufacture and retail purchase of food product during which the product is of satisfactory quality’ (IFT, 1974). Since all products have a variable but limited shelf life, the manufacturers make all attempts to maximize its keeping quality commensurate with the costs and pattern of handling and use by distributors, retailers and consumers. Obviously, the shelf life of food product must exceed the minimum distribution time required from the processors to the consumers to allow a reasonable period for home storage and use. Many food regulation authorities have now enacted laws for the food manufacturers to indicate the expiry date i.e. the date by which the food can be consumed, on the package.

A product’s shelf life is basically determined by the components of the system; the process used in manufacture; method of packaging; the time, temperature and relative humidity during transport and storage (Dethmers, 1979). Food products during storage normally undergo the following changes (IFT, 1974):

- Spoilate by bacterial or enzymatic action.
- Loss of aesthetic qualities (sensory properties) such as colour, flavour, texture, appearance, etc.
- Physical changes such as moisture evaporation, gain to/or from the surrounding, resulting into caking, surface dehydration, etc.
• Chemical reactions such as oxidation, hydrolysis, and reversion in fats, oxidation of pigments, breakdown of protein structure leading to texture changes, changes in functional and water binding properties; staling and non-enzymatic browning.
• Entrance of insects to the packaged food.
• Contamination from storage environment leading to foreign flavours.
• Loss of nutritive value.
• Interactions between product and package/container.

These shelf life determining losses can be quantified by appropriate physico-chemical and biochemical methods, and integrated into mathematical expressions useful for prediction purposes (Saguy and Karel, 1987, Singh, 1994). However, for such models to be meaningful from practical point of view, they have to be based on valid relationships between sensory and objective data (Patil, 1996).

What changes can occur in different types of foods during storage and how sensory quality affected is an important consideration. Growth of bacteria, molds and yeasts, enzymatic breakdown and staling are the main causes of deterioration in perishable foods. Usually bacterial deterioration in such foods begin well before chemical or physical changes and results in development of off flavour such as sour (acidic), malty, yeasty etc. Molds and yeasts also cause visible deterioration mainly on surface of the foods. Enzymatic activity may be of microbial origin or from natural system and cause undesirable degradation of fats, proteins and carbohydrates. Some major flavour defects associated with these changes are rancidity, staleness, bitterness, etc.

Chemical reactions during processing and storage are responsible for many flavour defects in foods notably cooked/caramelized/browning, oxidized, sunlight activated, rancid, bitter, goaty, old/stale, etc. Discolouration of many products also take place during storage. Several texture related changes, such as surface hardening and softening of products, oil separation, gelation, stickiness caking, crystallization, etc. may also result due to faulty packaging and improper storage conditions. Sensory evaluation has very useful role in identifying all such changes in fastest possible manner.

3.0 IMPORATANCE OF SENSORY EVALUATION

A number of quality assurance procedures are used to examine and maintain quality of a food product at different stages starting from reception of raw materials to surveillance of the finished product. These tests are physical, chemical, microbiological and sensory. Amongst all these methods, sensory evaluation is of paramount significance. The sensory quality has to be included in product evaluation since it is the only integrated multi-dimensional measurement with following advantages (Pal et al., 1995):

• It identifies the presence or absence of perceptible differences.
• The important sensory characteristics are measured in a fast and quantifiable manner.
• Identifies particular problem that can not be detected by other analytical and instrumental techniques.
• It helps in ensuring that the consumers get a consistent, non-defective and enjoyable product.

The sensory evaluation procedures have been studied in considerable details with the result that this scientific discipline has come to be recognized as of fairly objective in nature. The inherent variability of sensory evaluation by human subjects can be greatly overcome through appropriate selection and training procedures, coupled with application of statistical methods so as to take full advantage of the high sensitivity of human sense organs that even today surpass the most sophisticated instrumental means for flavour, texture and colour examination (Ogden, 1993).

4.0 SENSORY EVALUATION IN MONITORING SHELF LIFE

Storage stability studies heavily rely on sensory evaluation to determine the nature and extent of deteriorative changes and thereby the length of time required for product to become unacceptable for consumption. Attempts are often made to establish relationship between sensory, chemical, microbiological and instrumental data on the product quality. Various tests have been used to achieve these objectives.

Difference testing aimed at establishing whether or not there is a difference between the stored sample and the fresh one, may be used if the product is to be determined “best before”. In this case the time after which product shows a perceivable difference in quality vis-à-vis the fresh product as judged by t-test or least significant difference employing analysis of variance is taken as the shelf life. Intensity or quantitative sensory tests such as ranking, category (or interval) scaling and magnitude scaling would be useful in determining the minimum durability or “useful life” of the product date marked “use” by. Such methods enable the analyst to know after how long storage, the product will exhibit a certain amount of quality change, which is the maximum acceptable by the consumer.

However, often simple sensory tests such as hedonic rating of the product during storage is employed for establishing product shelf life. The 9-point hedonic scale has been used extensively for shelf life studies (Patel and Gupta, 1989; Arora et al., 1985). The scale is easily understood even by naive consumers with minimal instruction, and the product differences are reproducible with different groups of subjects. The results from use of this scale are most informative, since computations will yield means, variance measures and frequency distributions, all by order of presentation and magnitude of difference between products by subject and by panel; and the data can be converted to ranks as well, yielding product preferences (Amerine et al., 1965).

Under such situations involving perishable product evaluation, an arbitrary, preference or acceptability limit is taken to establish shelf life. Frequently a score of 6 is considered to be minimum acceptable when a 9-point hedonic scale is used (Patil and Gupta), 1982). Prajapati et al., (1992) however, determined shelf life of low-fat spread taking a score of 7 as the minimum acceptable in storage studies on soya-based table spread. Patel and Gupta (1989) used a 9-point rating scale (1-most undesirable; 9-most desirable) for periodical assessment by a trained
laboratory panel. These workers took 80% of the initial flavour score as the shelf-life determining limit. Shelf life may be based on evaluation of a single most important parameter such as flavour (Patel and Gupta, 1989) or other sensory attributes. In products like sweetened condensed milk where the deteriorative changes take place generally in respect of texture (age thickening) or colour (browning), a single character may be used as the shelf-life determining parameter. Patil and Patel (1992) developed prediction equations for consistency score of sweetened condensed milk that has a predominant tendency to age thickening. The equation was based on the viscoelastic constants viz., deformation modules and normal viscosity. Consistency score was obtained using a linear scale divided into five equal sections between two extremes; ‘normal consistency’ typical of a fresh product and ‘extreme thickening’ found in a custard-like, gelled product. Recently, a shelf life prediction model has been developed based on Mallard browning kinetics in sweetened condensed milk (Patel et al., 1994). This study involved colour measurement by a reflectance meter and by sensory panel indicated by decreasing scores viz. 13-14: slight browning, 10-12: moderate browning and 7-9: pronounced browning. A score of 10 was arbitrarily selected to be the minimum for an ‘acceptable’ product. Shelf life determined by such an approach would help “best buy” date marking on the product.

Arora et al., (1996) conducted studies on canned rasogolla to predict shelf life and were able to establish correlation between the product’s sensory, physicochemical and microbiological parameters.

While individual sensory attributes viz. colour, texture, flavour, etc. may be assessed for a stored product, it is usual also to have its ‘overall acceptability’ evaluated when a hedonic or similar scale is used. However, when evaluation is based on a score-card comprising different attributes (e.g. the USDA score cards for milk and milk products) often the ‘total score’ is taken to reflect the products ‘overall’ acceptability. Singh, 1991 considered total score of 60 out of 100 for the determination for shelf life. BIS has also prescribed its own sensory scale for grading the quality of different foods.

Purely descriptive assessment of product during storage could be of considerable help in shelf life determination, but without any numerical values attached to the product quality it becomes difficult to use such descriptive data. In a recent study, defect intensity rating for various sensory attributes of stored UHT milk has been found very useful (Patel et al., un-published results). Such quantitative descriptive analysis overcomes the weaknesses of pure descriptive tests (Ogden, 1993).

5.0 REFERENCES

1.0 INTRODUCTION

Food preservation is very important to prevent enormous losses due to poor post harvest handling of perishable agricultural commodities. The principal causes of spoilage in fruits and vegetables are the growth of spoilage microorganisms, the action of naturally occurring enzymes, chemical reactions, structural changes and conditions of the storage of fruits and vegetables. Preservation of perishable commodities is carried out by: i) physical means such as heating, drying or freezing ii) fermentation with the use of microorganisms, iii) addition of chemical preservatives. Foods can spoil through the adverse changes caused by the presence of enzymes, oxygen, or light, the loss of moisture or most important, the action of microorganisms. Preservatives used to prevent the changes caused by oxygen, light and enzymes include the antistaling agents, antioxidants and antibrowning compounds.

2.0 TYPES OF CHEMICAL PRESERVATIVES

Several antimicrobial substances have been used for centuries. Salt, sugar, wood smoke and vinegar have a long history of traditional use as flavouring and antimicrobial compounds. Apart from this, there are many chemicals, intended to prevent or retard microbial spoilage. These include the various organic acids, parabens, sulfites and nitrates.

Consumers are demanding more “convenience” form of foods as well as products less dependent on added preservatives. Newer researches towards product development have emphasized the need of minimum preservative/additive for extended shelf life. Processing operations, food composition, packaging system and added antimicrobial substances have a synergistic effect towards ensuring storage stability and safety of food products. Chemical additives are advantageous in maintaining the nutritional quality, enhancing the keeping quality, making fruits and vegetables attractive and helping in the processing. The preservative action of chemical preservative is governed by acidity of the product. These chemical additives are recommended for preserving acid products whose pH is either 4.5 or below.

2.1 Selection of chemical preservatives

The major factors for considering the selection of chemical preservatives, include:
Chemical preservative would never take the place of proper sanitation and good manufacturing practices. Often greater gains can be made in improving processing operations with good manufacturing practices by evaluating critical control points to reduce initial microbial loads that can be realized by formulation of the finished product. Good sanitary practices in combination with the system approach can reduce the need of additional food preservatives.

3.0 FOOD ACIDULANTS

Acidulants play an important role in the preservation of various food systems, either by controlling the growth of food pathogens by maintaining an appropriate pH or by directly interfering with microbial metabolism. The incorporation of acids into the product at sufficiently high levels can ensure a commercially sterile product. Acids also stabilize food colours, reduce turbidity, modify melt characteristics, prevent splattering or enhancing gelling properties. These acidulants are also used as leavening or inversion agents, emulsifiers, nutrients and dietary supplements.

3.1 Types of acidulants

3.1.1 Phosphoric acid and its salts

Phosphoric acid is the least expensive acidulant. The bulk of acid is used in flavoured carbonated beverages. It is used in cheeses and in brewing to adjust pH. Phosphoric acid also acts as a yeast stimulant, acting as a neutralizer for caustic soda in peeling of fruits, to clarify and acidity collagen in the production of gelatin, in the purification of vegetable oils and also in jams and jellies for gel formation.

3.1.2 Acetic acid and its salts

Acetic acid or vinegar is used as acidifier, flavour enhancer, flavouring agent, pH controlling agent, pickling agent, solvent and for its antimicrobial properties. Vinegars are extensively used in the preparation of salad dressings, sour and sweet pickles, sauces and ketchups, cheese chewing gums, baked goods and gravies. Acetic acid is also used in the curing of meat and in canning of certain vegetable and is often associated with it in fermented products such as pickles, sauerkraut and vinegar. It is also an effective antifungal agent at pH 3.5 against bread molds.
3.1.3 Propionic acid and its salts

FDA enlists propionic acid as permitted GRAS additive. Propionic acid and its salts are used primarily in baked products to suppress bacteria causing rope in the centre of bread and the growth of mold on both bread and cakes. It also acts as a mold inhibitor in cheese foods, and spreads. The antimicrobial activity of propionic acid is affected by pH. The antimicrobial activity increases at pH values approaching Pka value of 4.9 with a maximum pH of usefulness of 6.0.

3.1.4 Lactic acid and its salts

Lactic acid is used as an acidifier, antimicrobial agent curing agent, flavour enhancer, flavouring agent, pH controlling agent, pickling agent, solvent and carrier. Lactic acid is used in the manufacture of jam, jellies, sherbets, confectionery products and beverages. It is a preferred acidulant for adjusting acidity and ensuring the clarity of brines for pickles. The calcium salt of lactic acid is primarily used to preserve the firmness of apple slices during processing, to inhibit the discoloration of fruits and vegetables, as a gelling agent for dehydrated pectin and to improve the properties of dry milk powders, condensed milk and baked food products. Mono sodium salt of lactic acid is used as emulsifier, flavour enhancer, humectant, lye peeling agent and pH controlling agent.

3.1.5 Succinic acid and succinic anhydride

Succinic acid is used as flavour enhancer, neutralizing agent and pH controlling agent. The reactions of succinic acid with proteins are often used for modifying the plasticity of bread doughs. The derivatives of succinic acid can be used as flavouring agents or in combination with paraffin, as a protective coating for selected fruits and vegetables. It also acts as solubilizing agents in gums and hydrophilic colloid.

3.1.6 Fumaric acid and its salts

Fumaric acid imparts a sour taste solid acids. It blends very well with other food acidulants. FDA has approved its use in food, as an acidifier, curing, accelerator and flavouring agent. Fumaric acid is used extensively in fruit juice drinks, gelatin desserts, pie fillings, refrigerated biscuit doughs and wines. It is also used in preparing various emulsions and dough conditioners. Its limited solubility coupled with an extremely low rate of moisture absorption makes fumaric acid a valuable ingredient for extending the shelf life of powdered dry mixes.

3.1.7 Malic acid and malic anhydride

Malic acid is used as acidifier, flavour enhancer, flavouring agent, pH controlling agent and synergist for antioxidants. It is listed in FDA list of GRAS chemicals. It is an optional ingredient in the FDA standards for sherbets, water ices, fruit butters, preserves, jams and jellies, non-alcoholic carbonated beverages and fruit flavoured noncarbonated beverages. Malic acid provides excellent antibrowning properties in fruits.
3.1.8 *Tartaric acid and its salts*

The codex of Federal Regulations allows tartaric acid for use in foods as an acidifier, firming agent, flavour enhancer, flavouring agent, humectant, pH control agent and sequestrant. Tartaric acid, sodium and sodium-potassium tartarate and choline bitartrate are GRAS food additives when used in accordance with good manufacturing practices. Tartaric acid is an optional ingredient in fruit butters, fruit jellies, preserves and jams, in artificially sweetened jellies and preserves and in fruit sherbets. Tartaric acid is widely used in grape and lime flavoured beverages of all types because of its effect on the flavour.

3.1.9 *Citric acid and its salts*

Citric acid is approved for food uses as an acidifier, curing accelerator, dispersing agent, flavouring agent, sequestrant and as a synergist for antioxidants. FDA classifies citric acid and its sodium and potassium salts as GRAS food additives when used in accordance with the good manufacturing practices. Sodium citrate is listed as an optional ingredient in ice cream, while the acid is listed as an ingredient for fruit sherbets and water ices. Citric acid and its salts are widely used in ice cream, sherbets and ices, beverages, salted dressing, fruit preserves and in jams and jellies. It is also used as an acidulant in canned vegetables, while calcium citrate is permitted for firming peppers, potatoes, tomatoes and lima beans during processing. Citric acid is also used in enzyme preparations for clarifying fruit juices in dry dough and antioxidants for chocolate and cocoa. Citric acid is one of the major acidulants in carbonated beverage, imparting to them a tangy citrus flavour. It also acts as a preservative both in the syrup and in finished beverage products.

3.1.10 *Benzoic acid and its salts*

Benzoic acid and sodium benzoate is permitted to the maximum level of 0.1%. Benzoic acid and its sodium salt are most suitable for preserving foods and beverages that naturally are in a pH range 2.5 – 4.0. The narrow pH of its activity limits wider application of this preservative in foods. Benzoic acid and sodium benzoate are used to preserve carbonated and non carbonated beverages, fruit pulps and juices, jams and jellies, whole or liquid egg yolk, pickles, bakery products, salad dressings, sauces and ketchups. Sodium benzoate is more effective against yeasts and bacteria than molds. The antimicrobial activity varies with foods, its pH and water activity and with types and species of microorganisms. Pathogenic bacteria may be inhibited by concentrations of 0.01- 0.02% undissociated benzoic acid. As an antimicrobial agent, benzoate acts synergistically with sodium chloride, sucrose, boric acid, heat, carbon dioxide, and sulphur dioxide.

3.1.11 *Propionic acid and its salts*

Propionic acid occurs naturally in Swiss type cheeses at levels as high as 1% where it is formed by propionic bacterium bacteria, which are involved in ripening of these cheeses. It acts as mold inhibitor. Propionic acid and its salts involve in the preservation of baked goods, where they inhibit molds and rope forming bacteria. Sodium propionate is more effective preservative in the yeast-leavened products.
3.1.12 Sorbic acid and its salts

Similar to benzoic acid, sorbic acid is one of the widely used food preservatives in the world. Sorbates are classified as GRAS food additives, with no upper limit set for foods that are not covered by the standards of identity. Sorbates are used in more than 70 food products that have federal standards of identity. Sorbates exhibit inhibitory activity against a wide spectrum of yeasts, molds and bacteria including most food borne pathogens. As bacterial inhibitors, sorbates are least effective against lactic acid bacteria. They can be used to suppress yeasts during lactic fermentation. The inhibitory activity or sorbates is attributed to the undissociated acid molecule and hence is pH dependent. The upper limit for its activity is at about pH 6.5 in most applications, and the activity increases with decreasing pH. Sorbates are generally recognized as microbial growth retardants, rather than microbials. The activity of sorbic acid against microorganisms, is a function of synergistic or antagonistic interactions with product composition, pH, water activity, microbial flora, chemical additives, storage temperature, gas atmosphere and packaging. The activity of sorbate is increased as the pH approaches its dissociation constant (pKa = 4.76). Sorbic acid and its salts are widely used as preservatives for pickles and pickled products, condiments, spices, sherbet bases, fruit pulps and juices, jams and jellies, dried fruits, soft drinks, fruit syrups, yoghurt, sour cream, cheese, seafoods, meat and poultry products and a variety of bakery products.

4.0 PARABENS

Parabens are phenolic compounds of esters of para-hydroxy benzoic acid. Parabens are more effective over a wide pH range including pH 7.0 and above. Water solubility of parabens is inversely related to alkyl chain length (methyl > propyl > heptyl). However, as alkyl chain length increases inhibitory action generally increases. The FDA considers methyl and propyl parabens as GRAS, while n-heptyl may be used in beer, certain noncarbonated soft drinks and fruit based beverages. Methyl and propyl esters have application, in baked goods, beverages, flavour extracts, fruit products, jams, jellies, preserves, pickles, salted dressings and syrups.

5.0 SALTS OF SULPHITE, BISULPHITE AND METABISULPHITE

Salts of sulphite, bisulphite and metabisulphite is decomposed by weak acids such as citric, tartaric, malic and carbolic acids to form potassium salt and sulphur dioxide, which is liberated from potassium sulphurous acid with water, when added to the fruit juice or squash. Free sulphurous acid is more effective (120 times) than combined sulphurous acid. The undissociated sulphurous acid molecule prevents the multiplication of yeasts, while the sulphurous acid ion inhibits the growth of bacteria. Glucose, aldehydes, ketones,, pectin and breakdown products of pectin, etc., which are found in fruit juices, have the properties of combining with sulphur dioxide with the result that the effectiveness of sulphur dioxide is reduced.

Being more effective against molds than yeasts, sulphur dioxide has found wide use in the fermentation industries. Sulphur dioxide in dried fruits and vegetables not only protects certain nutrients and controls discoloration, but also is equally effective in controlling microbial and insect activities. Boiling or heating largely eliminates Sulphur dioxide, when the sulphured food is reconstituted. It cannot be used in the case of some of the naturally coloured juices like phalsa, jamun, pomegranate, strawberry pulp, etc. on account of its bleaching action on anthocyanin. It cannot also be used in products, which are to be packed in tin
container, because it not only acts on tin container causing pinholes, but also forms hydrogen sulphide, which has an unpleasant smell and also forms a black compound with the iron on the base plate of the tin container.

Sulphur dioxide is usually classified as an antimicrobial agent. It is also used in controlling enzymatic and non-enzymatic browning, preventing oxidation and modifying protein texture. It is also effective against the destruction of aflatoxin. Because of this versatile properties and cheapness, sulphur dioxide, sulphite and bisulphites are largely used by the food industry in production of wine, bear, dehydrated fruits and vegetables, fruit jams a well as juices. In dehydrated fruits and vegetables stored at room temperature, loss of thiamine after 28 days of storage ranged from 26 to 36% of the total content. In the presence of manganese, oxygen and glycine at the pH of food systems, sulphur dioxide catalyses to cause a rapid destruction of  \( \beta \) - carotene.

6.0 CURING AGENTS

Curing agents permitted for use in meat, poultry and fish products include sodium nitrate, potassium nitrate, sodium nitrite or potassium nitrite and their combinations. Ingredients such as ascorbic acid isoascorbic acid or erythorbic acid, sodium ascorbate, sodium erythorbate, fumaric acid, glucono-delta-lactone, sodium acid pyrophosphate, citric acid or sodium citrate may be used in combination with these curing agents to serve as curing accelerators. The addition of sodium nitrate in cured meat products fixes their colour, improves their flavour, inhibits  \textit{Clostridium botulinum} growth and toxin formation and stabilizes lipids against oxidation. Ascorbate and its isomer, erythorbate, act as curing accelerators and colour stabilizers, reduce lipid oxidation and inhibit the formation of carcinogenic N-nitroso compounds. USFDA permits the regulation of the use of sodium or potassium nitrate at the level of 1 oz/100 lb of meat in dry curing or 0.25 oz/100 lb of meat in chopped meat products.

Reduction of nitrate to nitrite occurs in foods and in the saliva. The toxicity of nitrate can be explained by its high degree of reactivity, especially at low pH, where it forms its protonated form of nitrous acid, which acts both as an oxidizing and as a nitrosating agent.

7.0 NISIN

Nisin is a bio-preservative in food systems. The bacteria producing nisin are  \textit{Lactobacillus lactis} subsp.  \textit{lactis}, Leuconocins of  \textit{Leuconostoc mesenteroides} and pediocins of  \textit{Pediococcus acidilactici}. Nisin is recognised for over 50 years for its antibacterial activity. It has been used extensively in different food systems such as dairy, meat, fish, vegetables wine and bear and has been found to be effective in preserving these foods against many gram positive spoilage and pathogenic bacteria with some limitations. It has been found to effectively control spoilage and pathogenic gram positive bacteria, spore formers in liquid milk, ice cream, cottage cheese and different meat products.

The mechanisms of action of nisin involves adsorption of nisin to specific or non-specific receptors on the cell envelopes of bacteria. The second phase involves pathological charges in the target cells.
Table: Properties of chemicals for preservation of Foods

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Effective pH range</th>
<th>Antimicrobial activity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzoic acid</td>
<td>2.5 – 4.0</td>
<td>Yeasts and mold, Food poisoning bacteria spore-forming bacteria</td>
<td>Phenolic taste, lipids decrease effectiveness</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>≤ 5.0</td>
<td>Spore forming bacteria especially rope forming bacteria, molds</td>
<td>Mold and rope inhibitors in bread not interfere with yeasts</td>
</tr>
<tr>
<td>Sorbic acid</td>
<td>Effective upto 6.5</td>
<td>Yeasts and mold, selective against bacteria, Gram + bacteria</td>
<td>Lipids decrease effectiveness, pungent odour and taste, limits use</td>
</tr>
<tr>
<td>Parabens</td>
<td>Wide pH range</td>
<td>Yeasts and molds Gram + bacteria</td>
<td>As alkyl chain length increase, inhibitory action increases</td>
</tr>
<tr>
<td></td>
<td>effective at pH 7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and above 8.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide and sulphites</td>
<td>≤ 4.5</td>
<td>Yeasts, molds, bacteria</td>
<td>Undissociated sulphurous acid is most active form, no activity against yeast</td>
</tr>
<tr>
<td>Nitrites and nitrates</td>
<td>More reactive at pH</td>
<td>Clostridium botulinum</td>
<td>Activity dependent on low a_w and NaCl</td>
</tr>
<tr>
<td></td>
<td>5.0 – 5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nisin</td>
<td>6.5 – 6.8</td>
<td>Gram + bacteria</td>
<td>Certain pasteurised processed cheese spreads</td>
</tr>
</tbody>
</table>

8.0 CONCLUSION

Food additive chemicals are an intricate part of our food supply. These chemicals help in prevention of food spoilage and deteriorative changes soon after the harvest. Proper storage of fresh produce and preservation can add value to the processed food products and also make these processed food products available throughout the year in highly acceptable form to the consumers.

9.0 REFERENCES

1.0 INTRODUCTION

The deteriorative processes that occur in foods after harvesting and during storage and distribution are unavoidable. If food in untreated, microbial deterioration becomes the dominant process affecting safety and quality. Even if the foods is treated to reduce or eliminate microbial contamination, chemical and physical deterioration become the dominant processes in determining storage life time and in altering product quality. Accordingly, if technological strategies are to be devised to retard such deterioration and to minimize the consequent loss of quality, it is crucial to understand the nature of physico-chemical changes (instabilities) in the constituents and the factors that control component degradation. Physico-chemical changes in foods directly related to the colour, flavour and texture of the foods. Ultimately delivering quality foods desired by consumers depends on being able either to modify the instability of major constituents or choose storage conditions that minimize the chemical or physical deterioration. Some of such major changes which act as quality indices are being mentioned below:

2.0 CHEMICAL CHANGES

2.1 Protein instability

Protein in foods, those that are unprocessed or minimally processed as well as those are processed to destroy spoilage and pathogenic micro organisms, are susceptible to chemical changes brought about by indigenous or exogenous components and influenced by various conditions of treatment and storage. Some of the more prevalent and significant reactions occurring during refrigeration or ambient storage are described below with a focus on non-enzymatic browning, proteolysis and denaturation.

2.2 Nonenzymatic browning

One of the most common reactions in foods is the non enzymatic browning reaction, the Maillard reaction. It can involve reducing sugars and amino groups on the protein, consequent changes in colour and texture of the proteins can occur under abusive storage conditions, because its Q-10 (the increase in the rate constant as temperature is raised by 10°C) in 3-4.
2.1.1 Consequences and control

The thermal processing involved in condensing and drying initiates a Maillard reaction between the reducing sugar and the amino containing molecules of foods. The Maillard reaction, other reactions following from it, continue during storage and eventually result in the development of brown colour, changes in solubility of powdered foods, loss of nutritional value (chiefly lysine availability) and stale flavours. These reactions may limit the shelf life of sterile concentrates and powders. Much of 5 hydroxy- methyl furfural produced by these reactions in sterile-concentrated skim milk occur during thermal processing but that the brown pigment is produced during storage and is protein bound. Commercial non fat powder and infant formulae stored at 30°C to 40°C for one month at a_w 0.8 become dark brown and lost 29 and 45% of their available lysine respectively. At a_w 0.2 or less the loss was greatly reduced. Available lysine was reduced by 12, 23 and 49% for non-fat dry milk stored at 4,20 and 37°C at a_w 0.75. At water activity 0.44 the loss of available lysine and browning increases. The greater deterioration at a_w 0.44 was attributed to the crystallization of lactose and release of moisture that occurred at this aw (La Grange and Hammond, 1995).

Many of the sulphur-containing flavours that are produced during heating capable of further reaction, particularly with carbonyls, and this can cause abatement of the heated flavour during storage and some time the generation of new flavours. Sulphur compounds dominate the flavour produced by milk heat treatment. Reps et al., (1987) showed that autoclaving milk gave rise to glyoxal and methyl glyoxal, presumably through carboxyl amine reaction. These dicarbonyl have shown to react with methionine and cysteine to produce many of the sulphur compounds identified in milk. Reaction of these dicarbonyls with phenylalanine account for many of the aromatic compounds identified in heated milk. Methyl glyoxal can dimerise to 2,5 dimethyl-4hydroxy3 (2H) furanone which may partly account for the caramelised flavours that are observed. Lactones and methyl ketones released from milk fat by heat treatment also may play a role in heated flavour (Scanlan et al., 1968).

Gu (1991) presented evidence that the stale flavour resulted primarily from reaction of free amino acids with carbonyl generated in the browning quality of protein foods due to Maillard reaction can occur during storage with minimal change in the nutritive value, it can be avoided by a proper selection of ingredients, time and temperature during thermal processing and storage conditions like aw and temperature. Conversely the nutritional value of the proteins should not be a significant problem as long as the foods is acceptable to the consumer from sensory point of view.

2.1.2 Proteolysis

Post harvest physiological changes and proteolysis due to spoilage microorganisms will not be discussed. Here the proteolysis means proteolytic changes occurring in foods that have low but discernible enzymatic activity. The main area of interest meat tenderization associated with aging and protein changes associated with storage in some dairy products (Barnett and Kim, 1998).
2.1.2.1 Meat

The meat tenderise with aging, which is presumably due to the action of lysosomal and other proteases. Tenderisation of meat can be enhanced by the use of exogenous enzymes such as papain, ficin and bromelain. The shelf life of the meat may also be shortened because of continued proteolytic activity. Microbial growth will also be enhanced because greater availability of low molecular weight substances. Meat that is frozen and then thawed will normally deteriorate rapidly even at refrigeration temperature. This deterioration may be due to the breakage of any intact lysosomes, thereby releasing a wide spectrum of active proteases. They will cause the meat to becomes musty mushy because of extensive proteolysis and the resultant low molecular weight substances will facilitate microbial growth.

2.1.2.2 Fish meat

Fish quality deteriorate after rigor mortis with proteolytic activity being a casual factor. The production of histamine, putrescine, tyramine and cadaverine is increased due to proteolysis the primary source of these compound is from histidine, arginine, tyrosine and lysine which are produced by proteolytic action. Proteolytic deterioration of fish meat continues even in the frozen state if the storage temperature is not low enough with some protein having a half life of as little as 5 days.

2.1.2.2 Dairy products

Cheese manufacture begins with the use of proteolytic enzymes such as rennet to cause milk to coagulate to produce cheese curd. During aging, continued proteolysis contributes to flavour and texture development. For some cheese types residual protease activity can have an adverse effect on quality. For example, the tensile strength of Mozzarella cheese decreases logarithmically with storage time due to protease activity. UHT processed milk eventually gel upon storage and develop off flavours even through there is no microbial growth. One of the proteases responsible for is plasmin, which probably enters the milk from blood in the forms of its precursor, plasminogen (Walstra and Jenness, 1984). In fresh milk, most of the enzyme is present as the precursor. Increased plasmin activity is observed after UHT treatment and plasminogens decrease with plasmin activity increases upon storage (Manji, 1987).

2.2 Lipid instability

Lipids are important constituents practically in all the foods. An understanding of the chemical and physical changes that lipids can undergo as well as of the mechanisms and consequences of such changes is fundamental to any consideration of foods quality. There is a commonality in such changes among all lipids despite their wide diversity in food with regard to their total amount, chemical composition, physical state etc. Oxidative or hydrolytic decomposition of lipids can lead to serious problems in bulk oil in a storage tank, in the continuous phase of triacylglycerols in butter, in milk fat globules, in the phospholipid bilayer in cell membrane, in tissue lipids in lean fish, in skin fat in chicken and in frying oil or dried food.
2.2.1 Lipolysis

The majority of natural lipids consists of fatty acids attached to glycerol through carboxylic ester bonds. Hydrolysis of the ester bonds catalyzed by acid, alkali, heat, moisture or lipolytic enzymes result in the liberation of per fatty acid. Enzyme may be present naturally in food or in constituents mixed with food; some could be associated with microbial contamination. Temperature, moisture and pH are among the factors control lipase activity.

Off favour resulting from hydrolytic rancidity are more likely to occur in fat containing relatively short chain fatty acid i.e. C 4-10). The potential for lipolysis in milk, however is minimized due to the structure of the milk emulsion, which limits physical contact between triacyl glycerol substance residing in fat glycerols and the lipase enzyme in the skim milk. Agitation during processing the native milk structure and promote enzyme substrate interaction. Although heat inactivates the lipolytic microorganisms, the lipases produced by them can survive normal pasteurization temperatures.

Among the cereal crops oats have high level of lipolytic activity. Increase in per fatty acids usually occurs during growth and post harvest treatment and results in poor quality oats and oat product (Galliard, 1983) Lipolysis in improperly stored wheat floor results in progressive deterioration of its baking quality.

In frying potato chips, potatoes with high moisture content are brought in contact with hot oil (180°C) and consequently suffer significant hydrolysis. Factors that lead to high levels of free fatty acids and poor shelf life include long oil turn over period, temperature, contamination from frying tanks and poor packaging and storage of the finished product. Lipase activity in spices and seasonings often results in poor quality of food products particularly among those containing coconut oil. Many typical flavours are produced where short chair fatty acids are hydrolysed by natural milk or microbial lipolytic enzymes (Nawar, 1998).

2.2.2 Oxidation

Lipid oxidation is of paramount important to food quality. It may lead to the development of rancid off flavours, cause change in colour texture, reduce shelf life and/or impair nutritional quality. However a limited degree of lipid oxidation is sometimes desirable, as in the formulation of typical flavours and aromas that are associated with cheese and fried food.

2.2.2.1 Types of oxidation

- Autoxidation; Lipid oxidation proceeds via a typical self propagating free radical mechanism where oxygen attach occurs mainly at positions adjacent to the double bounds.

- Singlet oxygen oxidation: In addition to the ground state (singlet oxygen, \(O_2^*\)) plays an important part in lipid oxidation. The formation of hydro peroxide by \(O_2\) proceeds via mechanisms different from those of free radical autoxidation. Oxygen is inserted at both ends of the double bond, which then shifts to yield an allylic hydroperoxide in trans configuration.
Enzymic oxidation; Lipoxygenases are responsible for enzymic oxidation of lipids. It is believed that iron, a constituent of lipoxygenase, play a key role in the mechanism by which the enzyme catalyses hydroperoxide formation. (Hau and Nawar, 1988). These enzymes act mainly on polyunsaturated fatty acids containing cis-cis,1,4-pentadiene systems and catalyse the formations of hydroperoxide intermediates similar to those formed by non-enzymic autoxidation.

The breakdown of hydroperoxides leading to the formation of volatile and non volatile product, may also be catalysed by enzyme (i.e. hydroperoxidase). Obviously due to the greater specificity in enzyme-catalysed formation and decomposition of fatty acid; hydroperoxide and other specific oxidation and products are encountered. The various factors which influence the lipid oxidation are free fatty acids, the fatty acids positions in triacylglycerols, oxygen concentration, temperature, water content, physical conditions, prooxidants and antioxidants.

2.2.2.2 Consequences and control

Although milk fat contains relatively low concentrations of polyunsaturated fatty acid (about 3%). These play the primary role in the development of oxidized flavours-vinyl ketones such as 1-octen-3 one or octa-1 cis 5 diene-3 one play a dominant role in the flavour of oxidized milk. The vinyl ketones themselves gives milk a metallic flavour but when blended with an aldehyde give a typical oxidized flavour.

Oxidation in dairy products also can be initiated by exposure to light (Korycka and Richardson, 1978; 1979 and 1980). But the irradiated flavours produced in this way are significantly different from those produced by metal-catalyzed oxidation. Riboflavin is the primary pigment involved in irradiated flavour. Light activated riboflavin is reduced by molecules such as methionine, producing sulphur compounds typical of irradiated flavour. The reduced riboflavin can react with oxygen can be quite rapid and lead to noticeable flavour in a few minutes to a few hours of exposure, depending on the intensity and wave length of the light.

Irradiated flavour often is the most common defect in market milk because of the wide spread sale of milk is translucent polyethylene in well lightened place. In powdered milk especially powdered whole milk, flavour deterioration can occur through fat oxidation. This can be affected by the amount of free fat on the particle surface, the water content of the powder, the sort of packaging used, storage temperature, exposure to light and the addition of antioxidants. The oxidation of cholestrol in spray dried powders may be a health concern (Hall and Linguert, 1984; and Cleveland and Harris, 1987).

A number precautionary measures based mainly on the various aspects considered above can be recommended for prolonged shelf-life that is limited by oxidation and for minimizing undesirable changes in the quality of edible oil and fat containing foods:

- Select high quality raw material (e.g. seeds with minimum damage, oils with low FFA content and high resistance to oxidation.
- Use high quality food ingredient (e.g. milk, nuts, spices)
- Use techniques that reduce substrate catalyst interaction (i.e. avoid cell disruption, contact with enzyme).
- Minimize contact with oxygen, light and/or trace metals.
- Minimize exposure to elevated temperature.
- Use packaging that provides a reasonable gas barrier during storage and distribution.
- Minimize surface area in contact with air.
- Design and maintain proper storage tanks and pipe line (e.g. stainless steel, if possible; glass lining, free of copper and copper alloys, frequent cleaning, minimal head space, lowest practical temperatures, protection for contamination with microorganisms and regular inspection)
- Use appropriate antioxidants.

3.0 PHYSICAL CHANGES

Beside non-enzymatic browning and lipid oxidation there are other physico-chemical changes take place during storage of food products which affect the texture, colour, flavour and overall acceptability of foods.

3.1 Viscosity, gelation and sedimentation

The factors limiting the shelf life and acceptability of liquid products are change in viscosity, precipitation and gelation. These reactions are seen typically in concentrated, sterile products. The traditional process for in-can sterilization of milks, supplemented with, judicious addition of phosphates, citrates and gums, typically produces products that are reasonably stable for over a year. However holding the concentrated product in refrigerated storage before canning, results in more rapid gelation (Halwalkar et al., 1983). When ultrahigh temperature processing and aseptic packaging is used, precipitation and gelation are a more common problem. The cause of those changes is not definitely established but may caused by incomplete destruction of the milk protease plasmin which in fairly heat stable. In any event the storage of UHT-sterilized milk is often accompanied by proteolysis (Harwalker and Vreeman, 1978; Mckenna and Singh 1991), but leads to the joining of casein micelles by thin, hair like linkages and gelation (Zadow and Hardham, 1981; Koning et al., 1994). Gelation often in proceeded by precipitation and an increase in viscosity (Newstead et al., 1978; Snoren et al., 1984). These changes are affected by extent of concentration, season and lactation of milk production, extent of heat treatment, temperature of storage, pH and addition of polyphosphate and other ions.

Sedimentation of protein in UHT milk occurred if the pH was less than 6.55 (Zadow and Hardham, 1981). Sequestering calcium reduced sedimentation. Harwalker and Vreeman 1978 found that the viscosity of UHT treated skim milk was much increased in 9 weeks, while samples with added phosphatase lasted 12 weeks. Both of these samples gelled by 18 weeks. Samples with added polyphosphate showed no increase in viscosity on gelation at 18 weeks. Mckenna and Singh (1991) reported that UHT processed reconstituted concentrated milk containing 0.075% Hexametaphosphate did not gel or because viscous for 6 months at 22°C. To achieve this shelf life at 30°C 0.075 to 0.15% Hexametaphosphate was needed.
3.2 Crystallization of lactose

The major detriment to the shelf life of dry milk products is moisture, to much moisture in processed dry milk and or moisture from the atmosphere getting into the product during storage. The dry lactose in milk powder is very hydroscopic and readily picks up moisture from the atmosphere. Amorphous lactose is formed when a solution (e.g. milk) is dried rapidly as in a spray drier or frozen. If the water content of amorphous lactose is low, say 3% crystallization may be postponed almost indefinitely; nucleation rate is negligible because of the extremely high viscosity of the solution. The product is however very hydrosopic, and when moisture content arises to about 8%, lactose hydrate starts to crystallize. But when crystallization of lactose caused by moisture uptake occurs in milk or whey powder, the result in caking, powder particles and concentrated together by crystalline lactose, forming large and strong lumps. (Walstra and Jenness, 1984). Controlling the moisture of milk/powder between 3.5 and 3.9% and maintaining this moisture level within package will assume a shelf life of at least one year from the date of processing and packaging (Laarange and Haurmond 1993).

3.3 Ice cream and frozen foods

Loss of quality during storage can result from physical, chemical and microbiological processes. Since ice cream is a frozen food and is consumed in the frozen state microbiological reasons for quality loss result from improper manufacturing conditions. Chemical reactions can take place, albeit slowly, at low temperature. Chemical reactions caused by oxidation can lead to a loss in flavour quality, development of off flavours or an interaction of these two leading to new/or characteristic flavour generation (Kilara, 1993).

Physical defects are however a major cause of consumer complaints and among the types of physical defects are:

- **Coarseness** – presence of large/nonuniform ice crystals
- **Butteriness** – clumping of destabilized fat globules
- **Sandiness** – presence of large insoluble lactose crystals
- **Crumbliness** – poor protein hydration due to moisture loss and other factors.

Coarseness and sandiness in Ice cream is due to fluctuating and high storage temperature whereas butteriness and crumbliness can be reduced or eliminated by use of stabilizers and emulsifiers, (Szczesniak, 1998)

Freezer burn is a major quality defect in frozen foods that is induced from the exposure of frozen food undergoes a phase change then there are more prominent undesirable changes, for example changes caused by thawing and refreezing of foods. Similarly, phase changes involving melting and solidifying of fats are detrimental to the quality of candies and other lipid containing confectionery items (Szczesniak, 1998).

4.0 CONCLUSION

During storage and distribution, foods are exposed to a wide range of environmental conditions. Environmental factors such as temperature humidity, oxygen and light can trigger several reaction mechanisms that may lead to food
degradation. As a consequence, food may be altered to such an extent that they are either rejected by consumer, or they may because harmful to the person consuming them. It is, therefore, imperative that a good understanding of different physico-reactions that cause food deterioration is gained prior to developing specific methods for the evaluation, monitoring and predicting the shelf life of foods.

5.0 REFERENCES


1.0 INTRODUCTION

Quality retention in foods has been shown to be greatly influenced by time and temperature exposure of the food during storage and handling. High storage temperatures will reduce the useful commercial life of the food product depending on the exposure time. Indicators which can detect the time-temperature history of the product will be an effective tool to monitor the quality of food. Several such devices which can indicate either a temperature that was reached, a duration of exposure to a temperature or an integration of both have been developed and reviewed in the past (Byrne, 1976; Dharmendra et al., 2000).

Time-temperature indicators are small, simple, inexpensive wireless devices that exhibit a time-temperature history of the food. The time-temperature changes are irreversible and can be measured. It mimics the change of a target quality parameter of food undergoing the same variable temperature exposure (Taoukis and Labuza, 1989a, b; Hendrickx et al., 1991). The target could be any safety or quality attribute of interest such as destruction of spores, inactivation of enzymes, loss of vitamins, texture or colour. Commercially available time-temperature indicators which can provide a simple means to monitor cumulative time and temperature exposure have been broadly classified into two categories. Partial history indicators respond only to temperature fluctuations that exceed a pre-determined threshold temperature and are used to detect severe temperature abuse. Full-history indicators respond to all temperature conditions and are useful for comparing different temperature histories (Wells and Singh, 1988a, b). These indicators do not record the precise temperature but monitor time-temperature history through irreversible change of colour or shape of indicator elements depending on their response mechanism (Blixt, 1983; Legrond et al., 1986; Wells and Singh, 1988a, b).

2.0 TYPES OF COMMERCIAL TTI

A number of TTIs based on different working principles are commercially available. Most of these TTIs are patented and very limited information are accessible. Some of the most widely used commercial continuous response TTIs are:
2.1 TTIs based on diffusion principle

Marketed as the Monitor Mark™ (3M Co., Paul, Minnesota, USA), the monitor consists of a pad saturated with the migrating chemical mixture, serving as a reservoir. Superimposed on the pad is the end of a long porous wick (the track) along which the chemical can diffuse.

Before use, the pad is separated from the wick by a barrier film so that no diffusion occurs. Upon activation by removal of the barrier, diffusion starts if the temperature is above the melting point of the chemical mixture. Fatty acid esters and phthalates (mixed with a blue dye) are the types of chemicals used viz. butyl stearate (melting point of 12°C), dimethyl phthalate (-1.1°C), and octyl octanoate (-17°C). The response of the indicator is the distance of the advancing “blue front” from the origin. The advancement of the diffusing substance can be viewed through the openings along the wick or measured on an appropriate scale with the whole length of the wick visible.

By varying the type and concentration of the ester, different melting temperatures and response life can be chosen. Thus the indicators can be used either as a CTTI, with critical temperature equal to the melting temperature of the ester, or as a TTI if the melting temperature is lower than the range of temperatures the food is stored at, e.g., below 0°C for refrigerated storage. The tags can have a shelf life of years before activation if they are kept at cool temperatures.

2.2 TTIs based on enzymatic reactions

Commercially available as I-point® Time Temperature Monitor (I-Point Biotechnologies A.B., Malmo, Sweden), the indicator is based on a colour change caused by a pH decrease resulting from a controlled enzymatic hydrolysis of lipid substrate. Before activation, the indicator consists of two separate compartments, in the form of plastic mini pouches. One compartment contains an aqueous solution of a lipolytic enzyme, such as pancreatic lipase. The other contains the lipid substrate absorbed in a pulverized polyvinyl chloride carrier which is suspended in an aqueous phase with a pH indicator.

Different combinations of enzyme-substrate types and concentrations can be used to give a variety of response life and temperature dependence. Usual substrates are glycerine tricapronate (tricaprin), tripelargonin, tributyrin, bis-3,5,5-trimethyl-hexyladipate (THA), and mixed esters of polyvalent alcohols and organic acids.

The indicator is activated by breaking the barrier that separates the two compartments by exertion of mechanical pressure either manually or with a special mechanical activator, mixing enzyme and the substrate. Hydrolysis of the substrate (e.g., tricaprin) causes release of an acid (e.g., caproic acid) and a drop in pH, translated into a colour change of the pH indicator. Colours 0 (green), 1 (yellow), and
3 (red) are printed around the reaction window to allow comparison and easy visual recognition and measurement of the colour change. The continuous colour change can also be measured instrumentally by a portable colorimeter, data for which could be developed into a simple kinetic model (Taoukis and Labuza, 1989a).

### 2.3 TTIs based on polymerization reaction

Marketed as LifeLines™ Fresh-Scan (previously LifeLines Freshness Monitor; LifeLines Technology Inc.; Morris Plains, New Jersey, USA), the operating principle of the TTI is based on the ability of disubstituted diacetylene crystals (R-C=C-C=C-R) to polymerize through a lattice-controlled solid-state reaction. The reaction proceeds via 1,4-addition polymerization, and the resulting polymer is highly coloured. During polymerization, the crystal structure of the monomer is usually retained, and the polymer crystals are chain aligned and are effectively one dimensional in their optical properties. The colour of the chain is due to the unsaturated, highly conjugated backbone. The side groups have little effect on the colour of the backbone but affect the reaction properties of the monomer. The change in colour measured as a decrease in reflectance is the basis of the TTI, and the response follows typical first order kinetics (ln reflectance vs time).

The indicator consists of an orthogonal piece of laminated paper, the front of which includes a strip with a thin coat of the colourless diacetylenic monomer and two bar codes. The indicating strip has a red background colour so that the change is perceived as a change from transparent to black.

![Image of TTI indicator](image)

A - Time-temperature indicator label.
B - Product specific information
C - Indicator type denotes relative sensitivity of colour - developing polymer material

Hand held micro computer to decode bar code information
2.4 TTIs based on analog principle

Manufactured under the trade name Smartlog™ (Remonsys Ltd., Bristol, England), these indicators are small, battery powered, microprocessor controlled devices which record the temperature history of the product during transport and storage. Higher costs of the product have however limited their widespread use. Such devices are placed at strategic locations with the product in the transport carrier to record temperature fluctuations both at the most stable and variable temperature environments.

2.5 Consumer readable TTIs

Consumer readable TTIs are simpler and lower in cost and function on the same principle as the continuous-response indicators. These are however designed to show a single end point, visually recognizable by consumers. Such TTIs are configured in a “bulls-eye” pattern, with the outer ring being a reference colour and the center circle changing colour. The center of the enzymatic type (I-point) shows a seemingly one step change from dark green to yellow, while the polymer type
(branded by LifeLines as FreshCheck™) shows a gradual darkening until the center matches the colour of the outer ring, signaling the end of shelf life. The consumer readable TTIs when tested using instrumental methods have been found to be reliable both under constant and variable temperature conditions (Sherlock et. al., 1991).

Steps involved in indicator labels preparation

Use by [date] unless center of label below is darker than ring

3.0 TTIs AND SHELF LIFE PREDICTION OF FOODS

The ability of TTI to function as cumulative recorders of temperature history from their activation time to the time each response measurement is taken, make them useful for two types of applications.

3.1 Correlations between TTIs response and quality characteristics

Several studies have been conducted to demonstrate the use of full-history time-temperature indicators in monitoring quality changes in different food systems
(Mistry and Kosikowski, 1983; Singh and Wells, 1985; Zall et al., 1986; Wells and Singh, 1988a). This has been accomplished by correlating the response of indicator models with sensory and objective changes in food quality when both the indicator and food were exposed to the same time-temperature conditions. High correlation suggested usefulness of such devices in monitoring food quality. Such studies though offer useful information, do not involve any modeling of the TTI response as a function of time and temperature and thus are applicable only for the specific foods and the exact conditions that were used. Extrapolation to similar foods or quality loss reactions, or even use of the correlation equations for the same foods at other temperatures or for fluctuating conditions, would not be accurate.

3.2 TTI's response and kinetic modeling

An alternative approach is to use the fundamentals of chemical kinetics to develop a scheme that allows the correlation of the response of a certain type of TTI to the change in quality and the remaining shelf life of a food product that has undergone any temperature exposure. Wells and Singh (1988b) prepared a generalized mathematical model to predict changes in food quality from the response of a full-history time-temperature indicator. It was suggested that because of the similar mathematical constructions a constant temperature equivalent can be estimated for any interval between successive indicator inspections. The constant temperature equivalent can then be used to predict the change in food quality during that same interval. Taoukis and Labuza (1989a) applied mathematical modeling using Arrhenius kinetics for evaluating three types of commercially available TTI. A scheme was introduced that allows the correlation of the TTI response, X, to the quality index of the food. X can be expressed as a function of time:

\[ F(X) = k_1 \exp\left(-\frac{E_A}{RT}\right) \]

Where \( F(X) \) is the response function of the TTI, \( t \) is the time and \( k \) the response rate constant; the constant \( k_1 \) and the activation energy \( E_A \) are the Arrhenius parameters, and \( T \) is the absolute temperature. For a variable temperature distribution, \( T(t) \), the response function can be expressed as:

\[ F(X) = \int_0^t \int_0^t k_1 \exp\left(-\frac{E_A}{RT(t)}\right) dt 
\]

Defining as effective temperature, \( T_{eff} \), the constant temperature that causes the same response or change as the variable temperature \( T(t) \), we have:

\[ F(X)_{eff} = k_1 \exp\left(\frac{E_A}{RT_{eff}}\right) \]

Similarly, the changes of quality \( A \) of the food can be modeled. Defining the food quality function \( f(A) \) such that \( f(A) = kt \) (the form of \( f(A) \) depends on the reaction order, e.g., \( f(A) = \ln\left(A_0/A_t\right) \) for 1st order) and using the food's Arrhenius parameters, \( k_A \) and \( E_A \) Eq. (2) and Eq. (3) can be applied for \( f(A) \). For a TTI going through the same temperature distribution, \( T(t) \) as the monitored food, the value of \( F(X)_{eff} \) is known from the response \( X \); \( T_{eff} \) can then be calculated from Eq. (3). \( T_{eff} \) and knowledge of the kinetic parameter of deterioration of the food allows the evaluation of \( f(A) \) and, hence, the quality loss of the product.
4.0 SIGNIFICANCE OF TTIs TO THE FOOD INDUSTRY

A closely monitored temperature exposure during distribution chain and an optimized stock rotation at the retail level based on the temperature of each product, instead of an often meaningless expiration date (Table 1), can lead to better control of quality and a significant decrease in food waste. TTI technology is thus compelling to the food industry for a number of reasons.

Table 1 Open dating terminology.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production date or pack date</td>
<td>Historical meaning; gives the date on which the product was manufactured or put into the final package. Used on prepackaged fresh fruits and vegetables, where shelf life depends on the freshness of the product when harvested.</td>
</tr>
<tr>
<td>Sell-by date</td>
<td>Helps in stock rotation to get the products out, so the consumers can purchase the product at a point which will still give them adequate time for home storage before the end of shelf life. Printed dates are usually very good guesses or industry practice.</td>
</tr>
<tr>
<td>Best-if-used-by date</td>
<td>The estimated point where the product quality loss reaches a level still generally acceptable but after which it fails to meet the high quality standard. Ambiguous date as to when the product should be taken off of the supermarket shelves, but confusing for the stock rotators.</td>
</tr>
<tr>
<td>Combination date</td>
<td>Best if used within ___ days of ___ date. The “___ days of” parts make this phrase a best-if-used-by-date, while the date given represents a sell-by date.</td>
</tr>
<tr>
<td>Use-by date</td>
<td>Commonly interpreted as “it dies or you die if you eat it”. The date determined by manufacturers as the end of the useful quality life of the product.</td>
</tr>
<tr>
<td>Freeze-by date</td>
<td>Often used on meat or poultry in conjunction with another date, such as a use-by date. Helps the consumer and helps the store in terms of product movement.</td>
</tr>
<tr>
<td>Closed or coded date</td>
<td>Numbers used by the industry that indicates production date, but not written for the consumer to understand. Important numbers in the case of product recalls.</td>
</tr>
</tbody>
</table>

4.1 Cold chain monitoring

Quality and safety of thermally sensitive products depend upon the cold chain, which is a term expressing the refrigeration from processor to receiver, to warehouse, to retail, to consumer. Temperature abuse has been proven to be cumulative, so each link in the chain is important. TTI “labels” attached to individual cases or pallets can give a measure of the preceding temperature conditions along the cold chain and integrate these preceding conditions. In the typical shipped product scenario, the TTI labels are activated at the shipping point, sense temperature during transit, and continue to sense temperature as the shipment is broken up, redistributed and kept in cold storage at multiple final destinations. This monitoring continues right up to the point at which retail sale occurs. The overall...
monitoring of the distribution system, thus allows for recognition and possible correction of the more problematic links.

4.2 Management of inventory

The more common system of inventory management that is used in conjunction with a product date stamping system is FIFO (First In, First Out). Using FIFO, the product with the soonest expiration date is preferentially placed on the retail shelf for sale. With this system, it is still possible to put spoiled product in front of a customer that is not fresh to the taste, or possibly not wholesome or safe. This is because the variation in the temperature history of any given product parcel is fairly large, and some may actually expire before the expiration date says they will. Thus when abuse temperature conditions are encountered during storage, transport and handling, the FIFO policy is unable to compensate for the increased deterioration, and the uniformity in the quality of the product distributed from the stockpile is compromised.

An alternative to this would be to determine issue of store on the basis of observed or estimated food quality rather than elapsed time in storage. This is called Least-Shelf-Life, First Out (LSFO) or Shortest-Remaining Shelf-Life (SRSL) policy. In this system, if the temperature sensing and the integration function of the tags shows an earlier signal in the three dots of the tag (signaling a lower remaining shelf life), then the product is rotated to the retail shelf. This rotation is totally independent of the product dating. Under this scenario, the possibility of placing “bad product thought good” in front of the consumer is almost reduced to zero. This policy would thus reduce food waste and provide more consistent quality at the time of issue for food items which have been exposed to differing temperature conditions.

4.3 Monitoring of quality or shelf life

Commercially available TTIs have been evaluated and found to give satisfactory prediction of a number of processed food quality. The studies conducted observed responses of several indicators and correlated with sensory and objective measures of food quality, when both indicator and food were exposed to the same temperature conditions. Highly significant statistical correlations were found between indicator response and food quality indices. TTIs have been also tested for prediction of remaining food quality and shelf life based on response information and kinetic models from isothermal testing. The prediction models have been satisfactorily employed even for products stored under variable temperature conditions.

4.4 HACCP advantages

TTI indicators now have a very important advantage-they can be custom manufactured to match the exact characteristics of the monitored food product as it relates to quality and safety. HACCP program designers are beginning to incorporate TTI tags and configure them to have colour change points which match the critical control points in the program. Since the tags give a distinct “yes/no” type of answer, they provide clear cut answers and do not require data inspection. This is ideal for HACCP, where the emphasis is on real time decision making and action. Several
industry organizations endorse the TTI concept and they are already acceptable in mandated HACCP program.

4.5 TTI and food safety

Minimally processed foods that are high in quality, nutritionally superior, easy to prepare and have extended shelf life present challenges to ensure microbial quality and safety. The chief microbial concerns associated with these products center around two types of microorganisms - psychrotrophic and mesophilic pathogens-that could grow during extended refrigerated storage or temperature abuse at some point during handling. The parameters that have to be seriously viewed in modeling quality are: an upper limit of the initial microbial population under a set quality control scheme based on HACCP and the food composition; the temperature behaviour of both lag phase and growth phase; an upper limit for microbial load corresponding to the end of shelf life; and the probability of pathogen growth and toxin production. From a regulatory standpoint, the presence of any viable pathogen or microbial toxin would make the food legally adulterated. However, a better alternative would be a statistical sampling scheme tied with a TTI. The design would have to be such that the TTI response would signal the food to be discarded even when the actual pathogenicity have not occurred. The use of TTIs for predicting potential pathogenic growth would however require accurate and extensive modeling of the temperature dependence of growth. Thus, if reliable data exist on the temperature behaviour of the different pathogens, a TTI tag could serve as a warning sign that a certain temperature has been exceeded for an unacceptable length of time.

5.0 CHALLENGES AND PROSPECTS

Although food industry in the developed economy have recognized the need for use of TTIs to reduce food waste and enhance food quality to the consumers, the cost, reliability and lack of scientific basis of application have been deterrent in their widespread use. Low demand of the TTIs have inhibited the production at mass scale. The economy of scale, therefore, do not permit manufacture of indicators at low cost (present cost estimates are up to 50 cent per unit). Smaller food processing units therefore can not afford to use these. The need of the hour is to develop prototypes that are reliable and can be produced at relatively lower costs. Furthermore, standardization of the unit being monitored at an appropriate size (case, pallet, car-load etc.) would also help in enhancing the cost-benefit ratio in favour of the indicators. Besides, most studies have used limited quantitative data without much meaningful mathematical modeling, so extrapolation of results to different type of foods and variable temperature conditions are a great limitation. Application of kinetic principles too has experienced certain limitations. The actual T_eff(food) and the estimated T_eff(TTI) many times differ for different temperature distributions. The three major source of error in the estimated T_eff(TTI) (Taoukis et al., 1991) are: the variation of TTI response which may increase as the TTI tag ages; the statistical uncertainty in the Arrhenius equation parameters; and the difference in activation energies between the TTI and the food. Thus, concerted research efforts are needed to generate sufficient information on accuracy and reliability of TTIs to temperature change particularly under isothermal storage conditions. Response of such indicators under variable temperature conditions and their stability prior to
activation are some of the areas that need to be thoroughly investigated. Particular emphasis need to be given to experimental determination of the kinetic parameters for TTIs prior to use. It would be useful for indicator manufacturer to report activation energies and reference rate constants to aid in the selection of TTIs for different purposes. More TTI designs and types are expected to meet the requirements of different food products. And finally, consumer education with regard to usefulness of TTIs in predicting quality and shelf life of foods will go a long way in ensuring greater acceptability of these indicators.

6.0 REFERENCES

1.0 INTRODUCTION

Antioxidants are present naturally in virtually all food commodities, providing them with a valuable degree of protection against oxidative attack. When food commodities are subjected to processing, such natural antioxidants are often depleted, whether physically, from the nature of the process itself or by chemical degradation. Thus, processed food products usually keep less well than do the commodities from which they originated. Ideally, food producers would like them to keep better. This objective can be achieved by blending natural products rich in antioxidants with processed foods, or by using well recognized antioxidants as food additives. Antioxidants are one of the principal ingredients that protect food quality by preventing oxidative deterioration of lipids. When present naturally or added externally to food they are functional in very small quantities, perhaps at levels of 0.01% or less. At higher concentration, they are themselves susceptible to oxidation or they can behave as pro-oxidants. It is important that quality assurance ensures the regulations that apply in different countries and for different class of food products are complied with. The major considerations for acceptability of such antioxidants are their activity and potential toxicity (Shahidi et al., 1992).

2.0 DESIRABLE QUALITIES OF FOOD ANTIOXIDANT

An ideal antioxidant should satisfy the following requirements:

- It should be active at extremely low concentrations (0.01 - 0.001%).
- The compound and its oxidation products must be non toxic even at doses much larger than those that normally would be ingested in food.
- It should impart no foreign flavour, odour, or colour to the food even after prolonged storage or heating.
- It should be easily incorporated into the substrate.
- Its antioxidant action should not be limited to the fat in which it is incorporated but should be transmitted to the food that subsequently might be prepared from this fat.
- It should be easily available and cost so little that its use will not significantly increase the price of food.
- To control its use in food, the antioxidant should be easy to detect, identify and measure.
3.0 MECHANISM

The classic route of auto oxidation includes initiation (Production of lipid free radicals), propagation and termination (production of non radicals products). Antioxidants can interfere with the oxidation process by reacting with free radicals, chelating catalytic metals and also by acting as oxygen scavengers.

\[
\text{Initiation} \quad \text{RH} \quad \rightarrow \quad \text{R}^* + \text{H}^* \quad -(1)
\]

\[
\text{Propagation} \quad \text{R}^* + \text{O}_2 \quad \rightarrow \quad \text{ROO}^* \quad -(2)
\]

\[
\text{ROO}^* + \text{RH} \quad \rightarrow \quad \text{R}^* + \text{ROOH} \quad -(3)
\]

\[
\text{Termination} \quad \text{R}^* + \text{R}^* \quad \text{Non Radical} \quad -(4)
\]

\[
\text{R}^* + \text{ROO}^* \quad \rightarrow \quad \text{Products}
\]

\[
\text{ROO}^* + \text{ROO}
\]

Reaction (1) is thermo dynamically difficult (activation energy of about 35kcal/mol), production of the first few radicals in necessary to begin the propagation reaction (Narwar, 1985). The reaction of a lipid with molecular oxygen in its excited singlet state or by metal catalysis or by exposure to light can form lipid peroxy radicals.

Lipid radicals are highly reactive and can readily undergo propagation reactions either by abstraction of a hydrogen atom from the \( \alpha \)-position adjacent to a double bond or by reaction with molecular oxygen in its ground state (Reaction-2).

The oxygenation reaction is very rapid having almost a zero activation energy, therefore the concentration of the peroxy radical (ROO*) is much higher than that of the alkyl radical (R*) in food systems in which oxygen is present. The peroxy radical ROO* can take part in all typical radical mediated reaction such as that in pathway 3. The sequence of Reactions 2 & 3 are repeated. Due to resonance stabilization of R* species, the reaction pathway is usually accompanied by a shift in the position of double bonds, thus resulting in the formation of isomeric hydroperoxides that often contain conjugated diene groups. (Narwar, 1985), Termination reactions may become important in edible oils heated at elevated temperatures, such as when large amounts of polymers are formed in frying oils. Hydro peroxide may also decompose to produce alcohols, aldehydes, Ketones, hydrocarbons etc (Gordon, 1990).

4.0 CLASSIFICATION

Antioxidants can be classified into two groups, namely primary or chain breaking antioxidants which can react with lipid radicals to convert them to more stable products and secondary or preventive antioxidants which reduce the rate of chain initiation by a variety of mechanisms

4.1 Primary antioxidants

They interfere with autoxidation by interrupting the chain propagation mechanism. In turn they are oxidized slowly in the process and normal autoxidation proceeds when the antioxidant has been destroyed completely. The compounds
most commonly used in foods are often called Phenolic antioxidants because the best known and most effective substance are polyphenols. Antioxidant activity, however is not restricted to the phenols and a number of other compounds, usually containing nitrogen or sulfur functional groups with electronic configuration similar to that of polyphenols are also powerful antioxidants. Most of the primary antioxidants are effective at extremely low concentrations with several of them, the effectiveness decreases as concentration is increased. At high levels they may even accelerate autoxidation. Primary antioxidants are most effective in animal fats that contain little natural stabilizer, while they are much less effective in vegetable oils which already may contain optimum amounts of naturally-occurring antioxidants.

**Mechanism**

AH (Antioxidant) interfere with lipid oxidation by rapid donation of a hydrogen atom to lipid radicals (Reaction 5 & 6). The latter reactions compete with chain propagation reactions.

\[
\begin{align*}
\text{ROO}^* + \text{AH} & \rightarrow \text{ROOH} + \text{A}^* \quad \text{-- (5)} \\
\text{RO}^* + \text{AH} & \rightarrow \text{ROH} + \text{A}^* \quad \text{-- (6)} \\
\text{ROO}^* + \text{A}^* & \rightarrow \text{ROOA} \quad \text{-- (7)} \\
\text{RO}^* + \text{A}^* & \rightarrow \text{ROA} \quad \text{-- (8)} \\
\text{ROO}^* + \text{RH} & \rightarrow \text{ROOH} + \text{R}^* \quad \text{-- (9)}
\end{align*}
\]

The above reactions are exothermic in nature. The resulting phenoxy radical itself must not initiate a new free radical or be subject to rapid oxidation by a chain reaction. In this respect, Phenolic antioxidants are excellent hydrogen or electron donors and in addition, their radical intermediates are relatively stable due to resonance delocalization and lack of suitable sites for attack by molecular oxygen.

The stability of the phenoxy radical is increased by bulky groups at the ortho position, e.g. in 2,6 di-tertiary-butyl, 4-methoxy-phenol or BHA (Muller *et al.*, 1957). Since these substances increase the steric hindrance in the region of the radicals, they further reduce the rate of possible propagation reactions that may occur. (Reaction, 10, 11, 12) involving antioxidant free radicals.

\[
\begin{align*}
\text{A}^* + \text{O}_2 & \rightarrow \text{AOO}^* \quad \text{-(10)} \\
\text{AOO}^* + \text{RH} & \rightarrow \text{AOOH} + \text{R}^* \quad \text{-(11)} \\
\text{A}^* + \text{RH} & \rightarrow \text{AH} + \text{R}^* \quad \text{-(12)}
\end{align*}
\]

Anti oxidative activity by donation of hydrogen atom is unlikely to be limited to Phenols. Also these may be added to foodstuffs as early as possible to achieve maximum protection against oxidation (Copper, 1983).

**Butylated hydroxy anisole (BHA) and Butylated hydroxy toluene (BHT)**

Commercial BHA is a mixture of two isomers, 3 tertiary-butyl-4-hydroxy anisole (90%) and 2 tertiary butyl 4-hydroxy anisole (10%). BHA is commercially
available as white waxy flakes and BHT is available as white crystalline compound. Both are extremely soluble in fats and insoluble in water. Both have a good carry-through effect, although BHA is slightly better in this respect. BHA is particularly useful in protecting the flavor and color of essential oils and is considered the most effective of all food approved antioxidants for this application (Stuckey, 1972). BHA is particularly effective in controlling the oxidation of short chain fatty acids (Dziezak, 1980). Due to their volatile nature, both BHA and BHT are important additives used in packaging materials because they are able to migrate into foods. (Porter, 1980). The antioxygenic action of BHA increases with concentration up to about 0.02% and remains approx. same at higher values. BHT does not have an optimum concentration and the stability of fats to which it is added continues to increase with concentration, although the rate of increase is less at higher levels. BHA & BHT show synergism when used in combination. The most important property of BHA which accounts for its great popularity as a food antioxidant is its ability to remain active in baked and fried foods.

The only toxicological problem with BHA concerns formation of lesions in the rat forestomach. High doses of BHA have a light proliferative effect on the esophagi of pig and monkey (Ito et al., 1986). JECFA has established an ADI of 0 to 0.5 mg/Kg body weight for BHA (Anon, 1987). It seems unlikely that the use of BHA as an antioxidant in foods present any hazards to humans.

An ADI of 0 to 0.125 mg/Kg b.w. is allocated for BHT (Anon, 1987). Studies have shown that BHT may cause internal and external hemorrhaging at high doses that is severe enough to cause death in some strains of mice and guinea pigs. This effect is due to the ability of BHT to reduce vitamin K depending blood clotting factors (Ito et al., 1986). BHT is toxic at lower doses than any of the other antioxidant reviewed here.

Tertiary-butyl hydroquinone (TBHQ)

TBHQ is regarded as the best antioxidant for protecting frying oils against oxidation. It provides good carry-through protection similar to that of BHA and BHT. It is adequately soluble in fats and does not complex with iron or copper. Chelating agents such as citric acid can further enhance the lipid stabilizing properties of TBHQ. This combination is used primarily in vegetable oils and shortenings but not exclusively for animal fats. Confectioneries, including nuts and candies also benefit from the addition of TBHQ or its mixtures (Buck, 1984). TBHQ can be used alone or in combination with BHA and/or BHT at a maximum amount of 0.02% or 200 ppm based on the fat content of foods, including essential oils.

TBHQ is allowed as a food antioxidant in USA but not permitted in EEC countries and Canada due to lack of adequate toxicological information acceptable to those countries (Tomasi, 1986; Barlow, 1990). More recent studies have indicated TBHQ may be mutagenic in Vivo, through this requires further study (VanEsch, G.J, 1986). An ADI of 0 to 0.2 mg/Kg b.w. is allocated for TBHQ (Anon, 1987).

Gallic acid and the Gallates

Gallic acid is soluble in water but nearly insoluble in fats. Esterification of the
carboxyl group with fatty alcohols gives esters, which become progressively less soluble in water and more soluble in fats as the molecular weight of the alcohol increases. Propyl Gallates (PG) is available as a white crystalline powder and is sparingly soluble in water. It has a m.p of 148°C, loses its effectiveness during heat processing. The gallates are not carry through antioxidants and their power to stabilize fried foods, baked pastries or crackers prepared from fats containing these compounds is very low. Its usage has been permitted in chewing given base at 0.1% and / or BHT at a total conc. of < 0.01%. Gallates have lower volatility and thus have less phenolic odour than monohydric phenols such as BHA & BHT (Dziezak, 1986). No positive mutagenic or carcinogenic activity has been shown for propyl gallates (Van Der et al, 1986). An ADI of 0 - 2.5 mg/Kg b.w. was allocated for propyl gallate which does not seem to have adverse effects in reproduction (Anon,1987). The present use of gallates as antioxidants in food is very unlikely to pose any hazard to human health.

Nordihydroguaiaretic acid (NDGA)

Pure NDGA is a white, crystalline solid, melting at 184-185°C and very slightly soluble in water and dilute acid. It is a typical phenolic antioxidant and, as such is much less active in vegetable oils than in animal fats. It has an optimum concentration beyond which it may increase the rate of oxidation of fats to which it is added. NDGA has very little carry through property, either in baked goods or in fried foods at concentration normally used for the protection of fats against rancidity. It is destroyed rapidly in fats heated to deep frying temperature (Kapadia et al., 1955).

Due to unfavourable toxicological findings, NDGA has been removed by US food and drug administration from its GRAS list. Today NDGA is no longer of practical importance in the food field.

Tocopherols

The tocopherols are widely distributed all through the vegetable kingdom and are considered to be the major antioxidants of vegetable and animal fats. Antioxidant efficiency is best at low levels and these compounds show an optimum concentration (0.01-0.02%) which when exceeded results in decreased stability. Antioxidant activity increases from the $\alpha$-compound to $\gamma$-isomer, while vitamin E activity increases in the reverse series. Dugan (1980) indicates that the tocopherols have been found to be effective in a number of products including bacon, baked goods, butterfat, lard, margarine, rapeseed oil etc. Tocopherols are considered as anti oxidants with limited carry-through activity and are relatively weak antioxidants.

JECFA has allocated an ADI of 0.15 to 2 mg/Kg b.w (Anon,1987). Extracts of naturally occurring mixed tocopherols and $\alpha$,$\gamma$, and $\delta$ tocopherols are permitted for use as antioxidants. Higher levels of Tocopherol acetate (400 to 500 mg) may produce adverse effects due to increased iodine uptake by the thyroid gland (Abdo et al., 1986). Even at high oral doses, no severe hepatotoxicity was observed in rats. However, excessive supplements of Vitamin E upto 1000 mg/day are potentially toxic.
4.2 Secondary antioxidants

4.21 Reducing agents \ Oxygen scavengers

Not all antioxidant activity is conferred by free-radical interceptors. Reducing agents which function by transferring hydrogen atoms also retard rancidity. e.g.:

**Ascorbyl palmitate**

A white or yellowish white crystalline powder characterized by a slight citrus like odour, is among the most effective food-approved agents for oxygen scavenging (Porter, 1972).

It has no restrictions on usage levels unlike other antioxidants that are limited to 0.02% of the fat. According to Cort (1982) Ascorbyl palmitate at 0.01% is more effective than BHA and BHT at 0.02%. Synergistic effect is noted with tocopherols. The compound is very slightly soluble in water and is more soluble in fats. JECFA has specified ADI levels of 0 to 1.25 mg/kg body weight for Ascorbyl palmitate (Anon, 1974). There is no information on the metabolism of Ascorbyl palmitate or stearate but is assumed that they break down into ascorbic acid.

**Sulfites**

Collectively referred to as sulfites- sulfur dioxide, sodium sulfite and sodium and potassium bisulfite and metabisulphite, these compounds are used as weak antioxidants in a variety of foods. Sulfites effectively control non-enzymatic browning as well as certain enzyme catalyzed reaction.

SO₂ Sulphurdioxide  SO₃²⁻ sulphite.  HSO₃⁻ bisulphite . S₂O₅²⁻ metabisulphite

**Ascorbic acid**

Vitamin C also function as an oxygen scavenger, making it particularly useful in canned or bottled products with a headspace of air (Cort, 1982). In its removal of oxygen from air or food, ascorbic acid is oxidized to form dehydro ascorbic acid thereby asserting its antioxidant action. Ascorbic acid synergizes the effect of tocopherol. It protects against oxidation in wines, beer, fruit, vegetables, beverages, butter and fish products. Levels of 1-6 mg/l can be found in beer white 50-70 mg of ascorbic acid are used per liter of wine containing 15-20 mg of free sulphorous acid (Takeda, 1986). The food additive uses of ascorbic acid and its derivatives are extremely unlikely to have any adverse effects. However, human studies indicate that ascorbic acid taken in high doses of 1 g / day or more may cause adverse reactions and increase urinary oxalate excretion in some individuals (Anon, 1981).

**Glucose oxidase**

It acts by removing dissolved or headspace oxygen. The enzyme catalyzes a reaction between oxygen and glucose yielding D-Gluconic acid and hydrogen peroxide. Catalase, a constituent of commercial glucose-oxidase system prevents the accumulation of hydrogen peroxide in the food since it hydrolyzes the hydrogen
peroxide to water and oxygen. Reaction proceeds until the glucose or oxygen substrate are exhausted. Its usage includes products such as citrus soft drinks, carbonated drinks, beer, wine, fountain syrups, mayonnaise, egg products. It has not been widely used in the food industry because of manufacturer's reluctance to add glucose to non sweet foods.

**Erythorbic acid**

Erythrobic acid and sodium erythorbate are strong reducing agents, acting as oxygen scavengers and reducing molecular oxygen. Use of erythorbic acid with citric acid has been proposed as an alternative to sulfites. When used at levels of 150-200 ppm it effectively suppresses oxidative deterioration in frozen fruits (Pfizer, 1986). It uses include beer, ale, cured pork, beef cuts, cured poultry.

**4.2.2 Chelating / Sequestering agents**

Classified as synergists, chelating agents complex with pro-oxidative metal ions such as iron and copper. An unshared pair of electrons in their molecular structures promotes the complexing action.

**Citric acid**

It is a highly effective sequesterant. Extensively used across the industry in a range of products. Usage levels for citric acid are typically 0.1-0.3% with the antioxidant at 100-200 ppm. Combined with other antioxidants, it prevents oxidative rancidity in dry sausage (0.003%). Fresh pork sausage (0.01%) & dried meats (0.01%). In fat, oils and fat containing foods, it chelates metal ions at usage levels of 0.005-0.02% (Pfizer, 1982).

It is highly soluble in water and almost insoluble in fats, but its esters are more soluble. It is readily decomposed by heat, but its thermal decomposition products are also good synergists.

**Poly phosphates**

They are the derivatives of phosphoric acid, also sequester metal ions. Short chain polyphosphate e.g. sodium acid pyrophosphate and sodium tripolyphosphate are the best. Phosphoric acid synergizes other antioxidants to guard against oxidative rancidity in vegetable shortenings (Monsanto, 1985).

**EDTA**

Its most common forms being calcium disodium EDTA and Disodium EDTA. Highly, stable complexes are formed by the sequestering action of EDTA on iron, copper and calcium. Maximum chelating efficiency occurs at higher pH values where the carboxyl groups are dissociated. Its effectiveness in opposing pro oxidant effects of copper has been shown in margarine during storage (Robards and Dilli, 1987).
**Phospholipids**

Secondary antioxidants effect of Phospholipids have been observed on frequent occasions. This has been ascribed to their metal chelating character (Brandt, P. *et al.*, 1973). Inactive complexes with metals have been found with Phosphatidyl Inositol and other acidic phospholipids but not with Phosphatidyl choline or Phosphatidyl ethanolamine (Pokorny, 1987). Phospholipids may act by releasing protons and bringing about the rapid decomposition of hydroperoxides without the formation of free radicals. An alternate mechanism may involve the regeneration of primary antioxidants (Brandt, P. *et al.*, 1973). Studies of synergism between Propyl gallate and Phosphotidyl ethanolamine led Dziedzic *et al.* (1986) to support the latter view.

5.0 CONCLUSION

Antioxidants are not used to any appreciable extent by the dairy industry, mainly because rancidity problems are not serious and are handled adequately in other ways. In addition, the use of antioxidants in dairy products usually results in decreased palatability. A number of antioxidants, however, can delay or prevent oxidative deterioration of dairy products.

6.0 REFERENCES


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ROLE OF MICROBIAL METABOLITES OF LACTIC ACID BACTERIA AS FOOD PRESERVATIVES

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1.0 INTRODUCTION

Presently consumers are looking for foods without any chemical preservatives, thus forcing the scientists to search for naturally occurring antimicrobial compounds for preservation. These naturally occurring antimicrobial compounds are termed as “biopreservatives” and include all those antimicrobials that are of plant, animal or microbial origin. Amongst all bio-preservatives, those from lactic and bacteria (LAB) employed in the manufacture of fermented foods are being studied extensively for their application in foods. LAB alters the sensory characteristics of raw materials often resulting in foods with increased nutritive and economic values. In developing and under-developed nations, many of the fermented foods are produced under relatively unhygienic conditions and yet retain a good record with respect to microbiological safety. This has been attributed to the synthesis by LAB of a variety of inhibiting compounds include organic acids, carbon dioxide, hydrogen peroxides, diacetyl, acetaldehyde, bacteriocins etc. The antimicrobial metalabolites of LAB are unique with respect to their role in the biopreservation of foods. This article is focused on inhibitory systems produced by LAB for their possible use in natural food preservation.

2.0 ANTIMICROBIAL COMPOUNDS FROM FERMENTATION

2.1 Organic acids

The controlled production of organic acid by microorganisms in-situ is an important form of biopreservation, since it can inhibit growth of spoilage microflora. Factors that determine the effectiveness of in-situ acidification include; buffering capacity, contaminants, fermentable carbohydrate and other ingredients and temperature. The most active antimicrobial organic acids are acetic, lactic, propionic, sorbic and benzoic acids. The concept of using LAB to prevent botulinal toxigensis though in-situ acid production exploits the inability of Clostridium botulinum to grow at pH < 4.8 as a defence at a temperature suitable for the growth. LAB and fermentable carbohydrate are added to the food. The LAB grow and produce acid in-situ only under conditions of appropriate temperature for the growth. Under proper refrigeration the LAB cannot grow and no acid is formed. The organic acid in undissociated form penetrate the cell membrane lipid bilayers easily and enters the cell. Once the acid dissociates inside the cell, the cell interior has a higher pH then the exterior. Bacteria maintain pH near neutrality to prevent conformational changes to the cell structural proteins, enzymes, nucleic acids and phospholipids. Protons
generated from intracellular dissociation of the organic acid acidify the cytoplasm and must be excluded to the exterior creating an electrochemical potential across the membrane called proton motive force.

2.2 Carbon dioxide

It is a major end-product in fermentation of hexoses by hetrofermentative LAB. The production of carbon dioxide is responsible for eye formation in many types of cheeses and contribute to the antagonistic activities of LAB. Its role is in creating an anaerobic environment by replacing existing molecular oxygen, its extracellular and intracellular pH decreasing effect and its destroying effect on the cell membrane. This protective role of carbon dioxide is especially important in the fermentation of vegetables and silages to prevent growth of molds.

2.3 Hydrogen peroxide

LAB produce hydrogen peroxide through electron transport, via flavin enzymes in the presence of oxygen and are reported to be antagonistic towards several other bacteria. Since LAB are catalase negative, the hydrogen peroxide produced is accumulated in growth medium to the extent of autoinhibitory levels. The partial antagonistic action of Lactobacillus spp. was noticed towards Staphylococcus aureus due to hydrogen peroxide. Lactococci added to raw milk can produce enough hydrogen peroxide to retard the growth of psychrotrophs. Although, the clearly observed antagonistic effect of lactic acid on one hand and hydrogen peroxide on the other hand, it has been suggested that in most cases the antibacterial action of starter culture bacteria is due to a combination of factors including low pH, organic acids, hydrogen peroxide and other inhibitory substances.

2.3 Diacetyl

Diacetyl, a metabolic end-product synthesized from pyruvate aerobically as well as anaerobically, is well recognized for its antimicrobial properties against food borne pathogens and spoilage microorganisms. Diacetyl is the characteristic aroma and flavour linked with butter, cottage cheese and butter milk. It is also found in red and white wines, brandy, roasted coffee, silage and many other fermented foods. It is more effective at a concentration of more than 400 μg/ml against Gram-negative bacteria, yeasts and molds, than that of Gram-positive bacteria. Diacetyl interferes with organic utilization by reacting with the arginine-binding protein of Gram-negative bacteria. Diacetyl has a bacteriocidal effect against strains of Yersinia, Aeromonas, Escherichia and Salmonella, but not against Listeria. Due to high levels necessary for inhibition and its volatility and flavour characteristics, diacetyl is not likely to be used as an additive to enhance preservation of traditional non-fermented foods. Because of its volatility it may be useful as an antiseptic agent for surfaces and utensils in manufacturing processes in food/agricultural industry.

2.4 Acetaldehyde

It is formed during carbohydrate metabolism of hetrofermentative LAB and is reduced to ethanol as a means of re-oxidation of pyridine nucleotides. Acetaldehyde is responsible for the typical aroma of yoghurt. The possible antagonistic effect of
acetaldehyde among different microorganisms is scantily available in literature. Acetaldehyde is produced in the range of 10-100 ppm by LAB and is found to inhibit certain foodborne pathogens e.g. *E. coli*, *Salmonella* and *Staphylococcus aureus*.

### 3.0 BACTERIOCINS

Bacteriocins are small, single or complex proteins or proteinaceous substances that exhibit bactericidal activity against a limited range of organisms, usually closely related to the producer. Bacteriocin production has been detected among all the members of LAB. The bacteriocin of LAB form a heterogenous group of antibacterial protein with regard to their inhibitory spectrum, physical and biochemical properties, mode of action and genetic elements associated with their production. The bacteriocins with a wide inhibitory spectrum are interesting because of their potential to control the growth of spoilage and pathogenic flora. Presently, there has been a great deal of research on the bacteriocin of LAB for natural preservation of foods.

#### 3.1 Application of bacteriocins in foods

A number of distinct applications are there for the use of bacteriocins in foods. They can be directly added to the food to inhibit spoilage-causing pathogenic microorganisms. Presently, nisin is the only available bacterocin for addition in pure form, but the efficacy of pediocin has also been proved. Bacteriocinogenic cultures can be added to non-fermented foods or used as starter culture in fermented foods to improve safety and quality. The use of defined bacteriocinogenic starter cultures offers many benefits like enhanced quality and consistency over that of indigenous bacteria. However, the indigenous microflora should be inactivated, since, it predominates the defined inocula. Due to this fact, the advantages of defined starters are more prominent in dairy sectors, where the indigenous microflora are inactivated during pasteurization. The following are some commonly used bacteriocins in different food categories.

#### 3.1.1 Nisin

It is added to milk, cheese and several other dairy products, canned foods and infant formulae worldwide. Nisin, the bacteriocin produced by certain strains of LAB, is the only bacteriocin that has been permitted for use in some foods in more than 45 countries including India. Nisin is designated as GRAS, as an antibacterial in some cheese spreads and is used commercially as an antimastitis teat dip. Nisin has potential as a treatment for ulcers, in personal hygiene, and as a sanitizing agent. The spores of *Clostridium botulinum* are less sensitive to nisin than that of vegetative cells of *Listeria monocytogenes*. Temperature is the major determinant of nisin’s inhibitory action. It is less effective at elevated temperature than at refrigeration temperatures. The threshold nisin levels are lower at decreasing temperatures. In most cases, nisin serves as a multiple-barrier inhibitory system and may be a significant adjunct to modified atmosphere storage. The combination of nisin with modified atmosphere is more effective than when either is used alone. In general, nisin is more effective at lower temperature, against lower spore loads, and under acidic conditions.
3.1.2 **Pediocin**

The inhibitory effect of pediococcal cultures is largely due to bacteriocins, termed as pediocins. These can be used as natural food preservatives owing to their broad spectrum and sensitivity to proteolytic enzymes. Pediocins inhibit vegetative cells of *Listeria monocytogenes* while being inactive against spores. It is used in form of powder or liquid culture to enhance the shelf-life of salad and salad dressings and as an antilisterial agent in foods such as cream, cottage cheese, meats and dairy products. Pediocin is more effective at 4°C than at 25°C against *L. monocytogenes*. Emulsifiers such as Tween 80, or the entrapment of the pediocin in multicellular vesicles increase pediocin-effectiveness in fatty foods. Generally, the pediocin rapidly reduces viability of *Listeria* and delays growth of the survivors.

### 3.2 Role of bacteriocin producing bacteria in non-fermented foods

The antilisterial applications of bacteriocins are derived better from the bacteriocinogenic strains rather than the pure bacteriocin. The degree of inhibition increases with decreasing temperatures and is greater under anaerobic condition than aerobic condition. *Lactobacillus bavaricus* inhibits listerial growth even in the absence of a fermentable carbohydrate. The addition of a fermentable carbohydrate, reduction of incubation temperatures, and increased lactobacillus/listeria inoculation ratios all increase the degree of inhibition.

### 3.3 Improved safety of fermented foods using bacteriocinogenic starter cultures

The application of a bacteriocinogenic starter culture can provide added value to the product, in case a food is going to be fermented by LAB. For example, the presence of a nisin-producing starter culture among strains used to make Cheddar cheese provides enough nisin to increase shelf life of pasteurized processed cheese. Bacteriocinogenic pediococci appear especially effective in fermented meats.

### 3.4 Targeted fermentation of foods using bacteriocinogenic starter culture

The use of undefined indigenous bacteria to ferment foods compromises product quality, makes true process control difficult and introduces uncontrolled variable in the manufacturing of fermented foods. These problems can be overcome by use of bacteriocinogenic starter cultures. Their ability to outgrow the indigenous microflora facilitate the use of defined starter cultures in unpasteurized foods an extremely important and promising application.

### 4.0 OTHER ANTIMICROBIAL SYSTEMS AND THEIR APPLICATION

#### 4.1 Reuterin

An antimicrobial substance having a molecular weight of 200, reuterin produced by *Lactobacillus reuteri* that inhabit the gastrointestinal tract of human and animals. Since, it is protease resistant, it is not considered as a bacteriocin. It is a potent, broad spectrum antimicrobial substance effective against Gram-negative (e.g. Salmonella and Shigella) and Gram-positive (e.g. Clostridium, Staphylococcus
and Listeria) bacteria, yeasts, fungi and protozoa. It is proposed that reuterin and / or reuterin-producing lactobacillus may have application in the preservation of food and feed by reducing pathogenic and spoilage microorganisms.

4.2 Antifungal substances

LAB may produce benzoic acid from hippuric acid during fermentation that significantly increase during manufacture of cheese and cultured dairy products. Benzoic acid restricts yeast growth in yoghurt and increases shelf life of product.

5.0 CONCLUSION

It is evident that antimicrobial spectrum of LAB is broad and can be caused by combinations of several factors. The biological methods of food preservation is only the beginning of a new era of food industry. Controlled acidification is conceptually straight-forward, but its successful application depends on a variety of product-specific factors. This has limited both its commercial use and academic interest in controlled acidification. The use of antimicrobial proteins, in one form or another, is definite to increase in future.

6.0 REFERENCES

1.0 INTRODUCTION

The emergence of microorganisms exhibiting resistance to the physical and chemical methods of traditional and conventional food preservation is increasingly proving a new hazard to the safety of our food supply. Therefore, it is critically important to prevent the spread of resistant organisms through the food systems and develop strategy to overcome the microbial resistance. Strategies for controlling the menace of bacterial resistance may include prevention of microbial adhesion, use of novel processing technologies, deployment of hurdle technology and modified packaging methods.

2.0 STRATEGIES FOR CONTROL

2.1 Prevention of microbial adhesion

Maintenance of cleanliness is essential to prevent the development of resistant strains of microorganisms on food-contact surfaces. Sometimes, the microtopography of a surface can jeopardise the cleaning operation when crevices and other surface imperfections protect the attached cells from the onslaught of cleaning. Hence proper design of equipment is a pre-requisite for eliminating cracks and dead area known to accommodate organic materials. Glass is preferred as a material for equipment fabrication because of its smooth and corrosion resistant surface. Stainless steel is impact resistant but is vulnerable to corrosion while rubber surfaces are liable to deterioration and may develop surface cracks having potential of harbouring microorganisms. Cleanability of surface is another criteria. Cleaning procedures fraught with danger of producing topographical defect in a surface will offer the increased number of attachment sites for build up of microorganisms. Application of sanitizer can also result in surface corrosion. All such factors should be taken into account while designing food contact equipment to prevent microbial adhesion.

Adhesion of bacteria to surface may lead to formation of biofilm. During the initial stages of biofilm development, a conditioning layer is formed as a result of absorption of protein on the surface. Gram negative bacteria are observed to be more adherent to glass than gram positive bacteria and also reported to have higher biofilm population after 2 days of culture than the latter. Adsorption of a bioactive compound onto a clean food contact surface can be looked upon as a possible preventive measures for initial microbial adhesion. Surfaces with the adsorbed antimicrobial peptide e.g. nisin have been found to decrease the incidence of surface...
contamination of *L. monocytogenes* on model food contact surfaces. Pretreatment of stainless steel surface with skim milk has been reported to substantially reduce the attachment of pathogens e.g. *S. aureus, S. macescens* and *L. monocytogenes*. Pretreatment with individual milk proteins $\alpha$, $\beta$ and $k$ also effects reduction in attachment. The release of atomic nitrogen by these proteins has been held responsible for this antibacterial effect.

The ultrasonic treatment can be employed to break down clumps of microorganism to facilitate the efficient destruction by subsequent bactericidal treatment with detergents and sanitizer.

### 2.2 Use of alternative technologies

A wide array of novel technologies can be looked upon as a viable alternative to prevalent technologies for efficient inactivation of microorganisms to ensure high safety and shelf-life of dairy and other food products. A number of such technologies with little microbial resistance established so far are being discussed in the following sections.

#### 2.2.1 Ohmic and inductive heating

Ohmic Heating (also known as Joule Heating, Electrical Resistance Heating, Direct Electrical Resistance Heating, Electro-heating and Electroconductive Heating) is defined as a process wherein electric currents are passed through other foods or other materials with the purpose of heating them. Ohmic heating is distinguished from other electrical heating methods either by the presence of electrodes contacting the food (absence of electrodes in microwave and inductive heating) and unrestricted frequency and waveform.

During Inductive Heating (IH), food is heated by electric currents sent by Oscillating electric magnetic fields created by electric coils placed in the close contact of food product. The IH can be differentiated from 'Microwave Heating' by the frequency (specially assigned in Microwave Heating and the nature of source (the need for coils and magnets in IH and a magnetron for Microwave Heating). The uniform and rapid heating even of particulates containing products ensures reduction in thermal abuse to the product as compared to conventional heating. The microbial inactivation is thermal in nature. A mild electroporation mechanism ensues during OH. Besides, low frequency (50-60 Hz) allows cell walls to build up charges and farm pores. On the contrary, in high frequency methods such as radio or microwave, electric field is reversed before building up of sufficient charges at the cell walls of microorganism.

#### 2.2.2 Microwave and radio frequency processing

These methods refer to the use of electro-magnetic waves of particular frequencies to generate heat in a material. The frequencies as approved by the Federal Communications Commission of USA for radio are 13.56 MHz, 27.12 MHz, and 40.68 MHz, and for Microwave are 915 MHz, 2450 MHz, 5800 MHz, and 24125 MHz. Microwave food processing generally uses the two frequencies of 2450 and 915 MHz. Of these two, former is used for home ovens while for industrial heating
Radio Frequency Heating can be accomplished by any of the frequencies mentioned above. Both these processes generate heat by two mechanisms, dielectric and ionic.

- **Dielectric Heating** - Water acts as the medium for such heating. Owing to its dipolar nature, water molecules try to follow the electric field associated with electromagnetic radiation as it oscillates at the very high frequencies. Such oscillations of water molecules generate heat.

- **Ionic Heating** - Oscillatory migration of ions in the food generates heat under the influence of the oscillating electric field.
  - Microwave heating is proposed to inactivate microorganisms by both thermal and non thermal mechanisms.
  - Thermal Inactivation - Microorganisms are inactivated in the typical fashion as in case of other biophysical processes e.g. destruction of enzymes, proteins, nucleic acids or other vital components and disruption of membranes.

Non-Thermal Inactivation - Four predominant theories have been used to explain this mechanism by Microwave Heating (also referred as Cold-Pasteurization):

- **Selective Heating** - According to this theory solid microorganisms are heated more effectively by microwaves than the surrounding medium and thus get destroyed more readily.
- **Electroporation** - The build-up of electrical potential across the membrane causes pore formation leading to leakage of cellular component.
- **Cell Membrane Rupture** - As per this theory voltage drop across membrane causes it to rupture.
- **Magnetic Field coupling** - This theory holds phenomenon of coupling of electro-magnetic energy with critical molecules in the cells responsible for disrupting internal components of the cell.

### 2.2.3 Ultraviolet light

Ultraviolet light processing engages the radiation from the ultraviolet (UV) region (especially 100-400 nm) of the electro-magnetic spectrum for the purpose of disinfections. Microbial inactivation takes place due to cross-linking of neighbouring pyrimidines nucleoside bases in the same DNA transcription and replication. There is a presence of UV repair system in some target microorganism capable of reversing such mutations but once the threshold of crosslinking has been crossed, the number of crosslinks are unreparable and cell death occurs.

### 2.2.4 Pulsed light technology

Intense and short duration pulses of broad spectrum white light is employed to achieve food preservation by this method. The spectrum of light for this technique
includes wavelength in the UV to infra red region. A wavelength distribution such that at least seventy percent of the electro-magnetic energy is within the range from 170 to 2600 nm is used. This technology is suitable for disinfections of packaging material, transparent packages and other surfaces and offers an alternative to use of chemical disinfectants and preservatives.

The lethality of light pulses is found to be different at different wavelength and pulsed light technology utilizes full spectrum of light ranging from UV light causing photochemical changes to infra red light producing photothermal changes. The microbial inactivation is due to the high peak power and broad spectrum of the flash. Nucleic acids are primary cellular targets undergoing inactivation due to chemical modification and cleavage of DNA. The nucleic acid destruction is followed by destabilization of proteins and membranes. Enzymic repair of DNA (possible in UV treatment) does not take place due to massive magnitude of damage. High energy and intensity of pulsed light are thought to amplify the known mechanisms of destruction of cellular components caused by individual wave lengths of light. The sum of the damage caused by the broad spectrum of light is proposed to produce extensive damage to DNA and other molecules.

2.2.5 Pulsed X-rays

This is a novel technology which utilises a solid opening switch to generate beam X-rays pulses of high intensity with opening times of 30 nanoseconds (ns) to a few ns. Microbial inactivation takes place due to direct interaction of the radiation with cell components and indirect action from radiolytic products such as the water radicals - H⁺ and OH⁻ and e⁻aq. The changes in chromosomal DNA/or cytoplasmic membrane can cause microbial inactivation or growth inhibition. No toxic effect on humans has been observed due to ions, excited atoms and molecules generated during irradiation.

2.2.6 Oscillating magnetic fields (OMFs)

The OMFs are known to possess the microbial inactivation potential. For applying this technology food sealed in a plastic bag is subjected to 1 to 100 pulses in an OMF with a frequency between 5 to 500 KHz at temp of 0-50° for a duration of 25 to 100 μs. Microbial inactivation is suggested to be based on the theory that the OMF may couple energy into the magnetically active parts of large critical molecules such as DNA.

2.2.7 Ultrasound energy

Ultrasound is energy generated by sound waves of 20,000 or more vibrations per second. Applications of ultrasonics are both non microbial and microbial. Nonmicrobial applications include non-destructive evaluation of internal quality of food products and process monitoring. Ultrasound energy inactivates vegetative cells of bacteria by causing intracellular cavitation. The fluctuating pressures induced under the ultrasonication process results into cycles of making and breaking of
microscopic bubbles. The micro-mechanical shocks created by these bubbles disrupt cellular structural and functional components to the extent of cell lysis.

### 2.2.8 Pulsed electric fields

High intensity pulsed electric field (PEF) processing employs pulses of high voltage (20-80 KV/cm) to foods placed between two electrodes. The PEF treatment is carried out at ambient sub ambient or slightly above ambient temperature for less than 1sec. The PEF is known to preserve the sensory and physico-chemical properties of foods. The PEF technology is characterized by a number of attributes e.g.

- generation of high electric field intensities
- the design of chambers that impart uniform treatment to foods with minimum increase in temp.
- design of electrodes that minimize the effect of electrolytes.

The PEF Technology is suggested to achieve microbial inactivation through two mechanisms.

- Electrical breakdown - The increase in the potential across the membrane effects reduction in the cell membrane thickness. An increase in the external field strength beyond a critical value causes the breakdown of membrane. Such break down results into the formation of transmembrane pores leading to immediate discharge at the membrane and disruption of membrane.
- Electroporation - Application of high voltage electric field pulses destabilizes the lipid bilayer and proteins of cell membrane. This results into increased permeability (membrane compression and partly swelling and eventual rupture of the cell membrane.

### 2.3 Hurdle technology

The application of hurdle preservation approach is being worked upon as a strategy to control and prevent the microbial growth during manufacture and storage of food products. To accomplish this preservation methods are combined to create a series of ‘hurdles’ throughout the process, each representing a barrier that must be overcome by bacteria to initiate food intoxication and spoilage. Such strategy is proposed to have two pronged effects on microbial adaptation and resistance:

- Metabolic Exhaustion - Simultaneous exposures of problematic microorganisms to different stresses will induce energy-consuming synthesis of several shock proteins, draining the microorganisms energy pool. The microorganisms will end-up exhausted metabolically. The combination of pressure with mild heat has successfully inactivated otherwise barotolerant strains. For instance, inactivation of *E. coli* 0157: H7 and *S. aureus* has been found more efficient when pressure (400-500 MPa) was combined with high temp (50°C). Such approaches have also been found effective for inactivating Bacillus and Clostridium spores. Similar synergistic action of combination of treatments (HHP, nisin and low temp.) has been frequently reported in literature. Low doses of nisin (0.06
μg/ml) and mild PEF treatment (16.7 kV/cm, 50 pulses each of 2 μs duration) has been reported to result in a reduction of 1.8 log units indicating synergy between these two treatments.

- Gene inactivation - Activation of genes for the synthesis of stress shock proteins should be more difficult if different stresses are received at the same time.

### 2.4 Modified atmospheric packaging (MAP)

The MAP is known to retard physiological reactions, respiration rates and microbial growth by appropriately modifying the gas levels of atmosphere surrounding the environment. Such modifications can be achieved by either passive or active methods. Passive methods are rather slow and involves reactions between food and its surrounding gases. Active packaging, however, a faster method can be achieved by gas flushing, vacuum packaging or using gas scavengers (substances absorbing the specific gases). Active packages with antimicrobial releasing systems (ethanol, sorbates, benzoates, propionates or bacteriocins) can be used to retard the growth of pathogens and spoilage microorganisms thus ensuring safety and extended shelf life of the product. An antimicrobial substance to be used for such purpose should meet the following criteria:

- Antimicrobial compounds must be effective against microorganism(s) of concern.
- Active compounds must diffuse at appropriate rates to be effective.
- Active compounds must not be toxic at concentration used.
- Must be approved as food additives.

### 3.0 REFERENCES

1.0 INTRODUCTION

Man has many competitors for the food he produces, animals particularly rodents, insects and microorganisms (moulds, yeasts, and bacteria), all cause wastage at various stages in the processing, stage, transport and sale of food. If microorganisms are permitted to flourish in food, they make it unattractive, and it wastes by putrefaction, fermentation, or mould growth. These organisms, particularly bacteria, can affect food and render it poisonous to man, thereby causing sickness and even death. Packaging plays a decisive role in achieving the objectives of waste prevention, safety and preservation.

2.0 DEFINITIONS OF PACKAGING

To appreciate the place of packaging in the preservation of food and world economy, it is essential to know what it is and how it functions. Packaging can be defined in the following several ways:

- Packaging is a coordinated system of preparing goods for transport, distribution, storage, retailing and end-use.
- Packaging is a means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost.
- Packaging is a techno-economic function aimed at minimizing costs of delivery while maximizing sales (and hence profit).
- Packaging is also described as a “complex, dynamic, scientific and controversial segment of business”. Packaging is certainly dynamic and is constantly changing. New materials need new methods, new methods demand new machinery, new machinery results in better quality, and better quality opens up new markets which require changes in packaging. The cycle then starts again.

Thus, at its most fundamental packaging contains, protects and preserves, and informs. At its most sophisticated, it provides two more functions – those of selling and convenience. In situations where the quality of products is high, in many instances almost the only difference between competitive brands lies in the packaging, and only the packaging influences the selling operation.

3.0 IMPORTANCE OF PACKAGING
Food must be available wherever there are people, and with modern population patterns this is seldom where it is grown or manufactured. Food, in interesting variety, must be available all the year round, irrespective of the growing season. It must be presented in a way that is convenient to purchase and use, and in most instances this means that it must be packaged.

3.1 Choice of suitable packaging

The choice of suitable packaging involves a number of considerations. For most food products there is an overriding objective: the package must provide the optimum protective properties to keep the product it encloses in good condition for its anticipated shelf life. Also to be considered are decisions which are subjective: the pack should be of the right shape and size and its graphics must attract the eye of purchaser. The development and design of appropriate packaging has made it possible to offer the consumer a wide variety of food from which to choose, with complete confidence in its wholesomeness, whether it is seasonable or not. In sophisticated societies, the food industry is the largest user of packaging at the consumer level.

The packaging technique and choice of a pack with appropriate barrier properties is designed to prevent destruction of food by microbial or insect attack, depending upon its physical nature, and also to preserve quality and nutritive value of many foods by the exclusion of oxygen and the control of moisture loss or gain.

3.2 Saving from wastage

Prevention of food waste is a vital objective for everyone. In sophisticated societies, the food manufacturer producing packaged foods is concerned to reduce waste in pursuit of an efficient business. For achieving this, it is essential to provide rapid and effective transport of the food to the processing and packaging plant to safeguard quality and quantity. In well publicized case of peas quick-frozen within two hours of harvesting not only is loss of peas prevented, but also loss of nutrients, compared with some methods of so-called “fresh” distribution. There is a further unseen benefit: all the pea hulls are left behind at the farm and the centres of population are kept free from much of the vegetable waste that would otherwise require disposal. Additionally, much of this waste can be used for animal food.

3.3 Packaging in “Portion”

Packaging in “portion” packs often helps the housewife to buy the quantity she needs and no more. It is one of the ironies that these aids to the avoidance of food waste are more readily available in affluent societies than in the developing world, where considerable losses can occur up to 25% (and sometimes more) of the food often for lack of proper packaging or storage conditions.

4.0 FOOD PRESERVATION vis–a–vis PACKAGING
Preservation of food is achieved by various means; however, food that is preserved has to be properly packed for shelf stability. Thus packaging of foods prevents the contact of preserved food with the outside environment, thus preserving the food.

5.0 ROLE OF PACKAGING

Packaging of foodstuffs is an integral part of the techniques used to extend the shelf life of food products like removal of heat (cold preservation), addition of heat (heating-thermal preservation), removal of water, cold sterilization or irradiation, binding moisture (salting/brining, addition of sugar), modifying food (acidification, fermentation) and addition of chemical preservatives.

5.1 Importance of barrier properties

The preservation of food product packed in a plastic film mainly depends on the maintaining of its original quality by protecting it against external deteriorative influences. This is achieved through the barrier properties of the packaging material. The required protection of the foodstuff may be achieved through the barrier properties of the packaging material. The required protection of the foodstuff may be achieved with a single layer of polymer or necessitates the use of multilayered films including different polymers, coating and metal foils. The barrier properties, hence the protecting capacity of a package, mainly originate from its permeability to gases and vapours that are noxious to the quality of the product.

5.1.1 Moisture barrier

For the majority of foods, the gain or loss of moisture leads to either a physical or biological defect. A loss of water may lead to undesirable drying detrimental to the texture of the product. A gain of water may lead water activity \( (a_w) \) to approach the region of microbial spoilage above \( a_w = 0.8 \).

5.1.2 Oxygen barrier

More harmful than moisture is oxygen for foods from plant or animal origin. Its fixation to the product is irreversible. It causes lipid oxidation and provokes rancidity especially when the package allows light transmittance. The other requirements for the preservation of the qualities (physical, chemical, sanitary, organoleptic) of the food are to prevent changes in taste, colour and odour and if a modified atmosphere is applied inside the package to maintain its composition in \( \text{CO}_2 \) and \( \text{N}_2 \). All the deterioration processes are time and temperature dependent. That is why the package very often bears a notice like ‘use before’ or ‘recommended deadline’.

6.0 SELECTION OF PACKAGING MATERIAL
The choice of packaging material should take into account all the deteriorative constrains as well as those caused by further treatment, storage and handling of the packaged food. The polymeric materials are so varied and their combinations so diverse that one can always find an appropriate film or laminate for a given application. However, the absolute barrier does not exist. It is necessary to adapt barrier properties to the anticipated shelf-life. The physical properties of the material, its processability and its interaction with the food together with its cost should be taken into account. One of the crucial criteria of choice is the knowledge of the permeability of the polymeric film to the gases and vapours of the environment that may affect the preservation of the food.

7.0 SAFETY OF PACKAGING MATERIALS

The polymeric food packaging materials are not completely inert and can transfer substances to the foods they come in contact with. Therefore, because of health and sanitation reasons, there are regulations that require the polymeric package materials to demonstrate a certain level of inertness towards the foods packaged within them. In Europe the harmonization of the European Community (EC) towards a common market starting 1st January 1993 has necessitated the introduction of a common set of laws concerning food contact materials. Similar laws concerning food contact materials are in force in other countries throughout the world.

One requirement of food contact law is that migration testing be carried out to determine the transfer of specific substances or the total (global) amount transferred to the food from the food contact package.

8.0 INFLUENCE ON FLAVOUR OF PACKAGED FOOD

Food packaging interactions may be mainly due to: migration, permeation and absorption. These can occur separately or simultaneously and affect food quality, e.g. food flavour aspects. Migration of packaging components, like residual monomers, additives or polymerization aids, can cause undesirable contamination of food. Migration of such component may adversely affect the quality of food, e.g. alteration of flavour. Permeation of gas and vapour, particularly of oxygen, water vapour and aroma components, is of considerable importance. Particularly in combination with light, a high rate of oxygen permeation can cause oxidation problems. A high water vapour permeation results in physical or physico-chemical alterations as wetting and drying, and can promote microbial spoilage. These reactions can lead to an indirect alteration of flavour, while direct flavour alteration can be caused by loss of flavour components from the food or by acquiring specific odours from the environment through the package.

Absorption phenomena can also influence the quality of the food. Absorption of aroma components by the package can cause a direct loss of flavour components from food, as absorbed flavour compounds can no longer contribute to the flavour of a foodstuff. Moreover, selective absorption of flavour components can result in an imbalance of the aroma and the product does not reach the consumer as was intended by the manufacturer.
9.0 CONCLUSION

The preservation of a packaged food and the increase in shelf-life require knowledge of the permeability of the plastic film to $O_2$, $CO_2$ and water vapour, as well as migration and flavour retention. However, there has been a tendency among food technologists to regard packaging as an afterthought - something to be dealt with as cheaply as possible when the more interesting problems of food technology have been tackled. Conversely, packaging producers have often regarded the food industry as one their major markets. In fact, food packaging is about fifty percent food chemistry and fifty percent packaging, and product and package must be considered together.

10.0 REFERENCES

1.0 INTRODUCTION

Convenience foods are of great demand in the market. The consumer in 21st century, is more demanding and discriminating and is more concerned about basic issues such as food safety, diet, use of additives and product labeling. The shelf life of perishable foods such as meat, poultry, fish, fruits, vegetables and bakery products is limited in the presence of normal air by two principal factors—the chemical effects of atmospheric oxygen and the growth of effect of aerobic spoilage microorganisms. These factors either individually or in association with one another bring about changes in flavour, colour and leading to an overall deterioration in the quality.

Modification of the atmosphere within the package by reducing the oxygen content while increasing the levels of carbon dioxide and/or nitrogen has been shown to significantly extend the shelf life of perishable foods at low temperature.

Modified atmosphere packaging (MAP) is a form of packaging involving the removal of air from the pack and its replacement with a single gas or mixture of gases. The gas mixture used is dependent on the type of product. The gaseous atmosphere changes continuously throughout the storage period due to factors such as respiration of the packed product, biochemical changes and the slow permeation of gases through the container. The foods packaged in modified atmospheres include raw and cooked meats, poultry and fish, vegetables and fruits, fresh pasta, cheese, bakery products, potato chips, coffee and tea.

2.0 METHODS OF ATMOSPHERE MODIFICATION IN PACKAGED FOODS

2.1 Vacuum packing

In vacuum packing, the oxygen level is reduced to less than 1%. In the vacuum packed meat, respiration of meat quickly consumes the residual oxygen replacing it with carbon dioxide which eventually increases to 10-20% within the package.

2.1.1 Mechanical air replacement

2.1.1.1 Gas flushing

A continuous stream of gas is injected into the package to replace the air. This dilutes the air in the headspace surrounding the food product. When most of
the air has been replaced the package is sealed. Typical residual oxygen levels in gas flushed packs are 2-5% oxygen.

2.1.1.2 *Compensated vacuum*

This process first applies a vacuum to remove the air from inside a perforated or thermoformed container holding the food and then introduces the desired gas or gas mixtures. Since this is two-stage process, the speed of operation of the equipment is slower than the gas flushing technique.

2.1.2 *Modified atmosphere generation*

2.1.2.1 *Passive atmosphere generation*

Vegetables and fruits continue to respire after harvest, consuming oxygen and producing carbon dioxide and water vapour. If the respiration characteristics of the commodity can be accurately matched to the permeability of the film used for packaging then a favourable modified atmosphere can be created passively within the package. Equilibrium modified atmosphere containing 2-5% oxygen and 3-8% carbon dioxide have been shown to delay maturation and softening of vegetables, reduce chlorophyll degradation, microbial spoilage and enzymatic browning.

2.1.2.2 *Active packaging*

The incorporation of certain additives into packaging film or within packaging containers to modify the headspace atmosphere and to extend product shelf life is referred to as active packaging. Active packaging is created by the use of oxygen absorbents, carbon dioxide absorbents/emitters and ethylene absorbents.

3.0 **GASES IN MAP**

Usually oxygen, nitrogen, carbon monoxide, other gases such as chlorine, ethylene dioxide, nitrogen dioxide, propylene oxide, sulphur dioxide and combination of gases for replacing the air surrounding the food in the package are used.

Oxygen is most important gas to be used metabolically by both aerobic spoilage microorganisms and plant tissues and taking parts in some enzymatic reaction, in food, including the oxygenation of myoglobin in meat, oxidation of fat and vitamins and flavours. Carbon dioxide has a powerful inhibitory effect against gram negative, aerobic spoilage bacteria such as Pseudomonas, species, which cause off colour and flavour defects in meat, poultry and fish. Nitrogen is an inert tasteless gas with low solubility in both water and lipid. It is used to replace oxygen so as to delay oxidative rancidity and inhibit the growth of aerobic microorganisms.

4.0 **FILMS FOR MAP FOOD**

4.1 *Low density polyethylene (LDPE)*

It is a copolymer of ethylene and vinyl acetate and has superior sealing properties.
4.2 Linear low density polyethylene (LLDPE)

- Better hot tack
- Greater stiffness
- Allows down gauging
- Better impact strength
- Higher elongation potential
- Better heat resistance

4.3 High density polyethylene (DDPE)

This has higher softening point than the lower density polyethylene, provides superior barrier properties and is a harder film.

4.4 Polypropylene

It is chemically similar to polyethylene and can be extruded or co-extruded with a moreover element to provide a heat sealable characteristics. It provides higher ranges of moisture vapour barrier and also provides much greater barrier to gases.

4.5 Ionomers

Ionomer has a high tack strength and will seal through a level of surface contamination. It can be used in extrusion coating.

4.6 Ethylene vinyl acetate copolymers (EVA)

It is a polymer with high flexibility in sheet form with permeability to water vapour and gases higher than that of low density polythene.

4.7 Polyvinyl chloride (PVC)

It is a good gas barrier and a moderate barrier to moisture vapour. It has excellent oil and grease resistance and in its unplasticised form, it is capable of smooth, even forming into shallow or deep trays.

4.8 Polyvinylidene chloride (PVDC) copolymer

It is used in MAP as a gas barrier coating for lidding films and in film form as a sandwiched barrier web. It has outstanding properties, with respect to its barrier levels, with low permeability to water vapour and gases.

4.9 Polystyrene (PS)

Polystyrene is a clear thermoplastic with a high tensile strength but a poor barrier to moisture vapour and gases.

4.10 High impact polystyrene

This is an opaque, thermo formable moderately low gas barrier film and consequently a component of laminate.
4.11 Barex

It is acrylonitrile copolymerised with methylacrylate and a small percentage of butadiene/acrylonitrile rubber. It is a clear polymer with excellent gas barrier properties.

4.12 Polyamides

These are tough films with high tensile strength and good resistance to abrasion, but these are slightly hygroscopic and the mechanical properties are altered by water absorption.

4.13 Polyethylene terephthalate (PET)

Polyester is used in various forms in modified atmosphere packaging as a low gauge oriented film of high clarity for lidding films and in crystalline or amorphous form as in line performed or thermoformed trays.

5.0 MODIFIED ATMOSPHERE PACKAGING OF FRUITS AND VEGETABLES

India is the largest producer of fruits and vegetables. Post harvest handling, packaging, transport, storage and marketing of fruits and vegetables involve a number of problem mainly because of the diverse size and shape and nature of vegetables. Post harvest losses in fruits and vegetables are as high as 30-50%, thus causing the losses more than Rs. 3000 crore per annum. MAP of fruits and vegetables involves solution of correct intermediary permeable membrane when the rates of O$_2$ and CO$_2$ transmission through the package equal, the products respiration rate. MAP conditions are created inside the packages by the commodity itself and/or by active modification. Commodity generated or passive MA is evolved as a consequence of the commodity’s respiration. It is a film of suitable permeability for developing an optimum equilibrium modified atmosphere (EMA) within the package. On the other hand, active modification involves creating a slight vacuum inside the package and replacing it with a desired mixture of gases so as to establish desired EMA quickly compared to a passively generated EMA.

Another active modification technique is the use of carbon dioxide or ethylene absorbers within the package to prevent the build up of the particular gas within the package. This method is called active packaging. Compounds like hydrated lime, activated charcoal, magnesium oxide are known to absorb carbon dioxide, while iron powder is known to absorb oxygen. Potassium permanganate, squalene and phenyl methyl silicone can be used to absorb ethylene within the packages. These scavengers can be held in small sachets within the packages or impregnated in the wrappers.

Commercial use of gas scavengers in MAP is introduced, as ToMAHtoe$^R$. This system contains tray packs of four tomatoes, shipped to the retail stores in a polyethylene-master container containing a carbon dioxide absorbent. Oxygen level is balanced between the permeability of the PE and respiration of fruits. This system enables to improve the fruit quality over most commercial supplies by harvesting the
fruits at a more mature stage. The MAP retards softening the tomato fruits, while holding at ambient temperature, and also allows for optimum flavour development. The product has a consistent quality, which has been the most deciding factor for its popularity.

6.0 BENEFITS OF MAP

Storage of fruits and vegetables under MAP is known to extend the shelf life of food by 1.5 – 4.0 fold under refrigerated storage. Storage under MAP would lead to an extension of storage life by retarding deteriorative changes and better retention of commodities. The altered atmosphere can act in any of the following ways:

i) Physiological metabolism leading to senescence is slowed down by the elevated carbon dioxide and decreased oxygen level in the storage atmosphere.

ii) Slow down the rate of production of ethylene and also the effects of ethylene-like textural softening.

iii) Due to retardation of senescence, the commodity is better maintained and chances of microbial spoilage are reduced.

iv) In the green leafy vegetables, chlorophyll is better preserved and browning due to enzymatic reactions is retarded.

v) Better retention of cellular components like sugars, organic acids, cellular proteins and flavour compounds.

vi) Semi-controlled manufacturing options.

vii) Reduction of waste throughout distribution.

viii) Reduction of labour and waste at the retail level.

ix) Favourable economics due to reduction of handling and distribution of unwanted or low grade product.

x) Preservative free product.

7.0 MICROBIAL SAFETY TOWARDS MAP

Suppression of normal spoilage flora may result in organoleptically acceptable product while either allowing or enhancing the growth of pathogenic organisms. Non-proteolytic psychrotrophic strains of *Clostridium botulinum* have been the major safety concern. These strain can grow and may produce toxin without signs of spoilage, which may also be absent as a result of an inhibition of the normal spoilage flora. Concerns have also been raised about the ability of other psychrotropic pathogens such as Aeromonas, Listeria and Yersinia to grow in MAP products.

In fruits and vegetables, the microflora mainly consists of bacteria, fungi and yeasts. Their type and number vary to great extent depending upon the environment and cultural conditions. The most common bacterial genera reported are Pseudomonas, Flavboaacterium and Corynoform. MAP is known to bring a shift in
the microbial population of fruits vegetables with response to various factors such as storage atmosphere and ability of the produce to support microbial growth.

8.0 BIO-CHEMICAL AND PHYSICOCOLOGICAL CHANGES TOWARDS MAP

In MAP storage conditions, the oxygen concentration drops below 2%, anaerobic respiration takes place, thereby leading to accumulation of ethanol and aldehyde. Reduction of oxygen below the tolerance limit, aldehyde and ketones may be formed which may lead to produce off flavour defect to the product. During storage of broccoli at the oxygen concentration of $\leq 0.5\%$, MAP leads to the formation of many compounds such as ethanol, methanethiol, hydrogen sulphide, acetaldehyde, methylacetate, acetone, etc. which imparts off flavour to broccoli.

9.0 WORLD SCENARIO OF MAP

There has been significant growth in the marketing of fruits and vegetables under MAP in countries like France, UK and USA. The MA packed commodities include a range of prepared vegetable such as salad cut lettuce, shredded cabbage, pealed and sliced potatoes, beets, diced or chopped green peppers, celery and chopped onions. Popularity of prepared vegetables is due to the need for convenience and consumer perception. The super markets in these developed countries are involved in the marketing of such products with their effective distribution system, which can ensure quick distribution under chilled conditions.

10.0 CONCLUSION

Modified atmosphere packaging is becoming increasingly popular as an effective supplements to refrigeration, especially in the present era of consumer awareness towards residues of pesticides, additives and preservatives in foods and of the economic need to sufficiently extend the storage life of fresh fruits and vegetables. MAP is popular for raw and cooked meats, poultry and fish, vegetables and fruits, fresh pasta, cheese, bakery products, potato chips, coffee and tea. MAP involves lowering the oxygen level to 2% and elevating carbon dioxide level in the storage atmosphere to 3-5%. The use of MAP is increasingly used in developed countries and the demand is increasing.

11.0 REFERENCES

1.0 INTRODUCTION

The most important task of food packaging is to protect the contents from changes and in doing so preserve the quality of food during storage. They should provide a sort of inert barrier that prevent the interaction of food product with external environment and also prevent mass transport between the packaging and the product. Despite their inertness, the food products undergo various kind of physico-chemical changes within the package during storage.

The packaging concept is determined by the demands of both the consumer and the product. New technological developments, environmental awareness, and changes in the consumer market force the packaging technologists to consider an increasing number of factors when designing a package (Cecilia, 2000)

A variety of packaging technologies are being developed to provide consumers with high quality, products that have a long shelf life. Technologies such as controlled-atmosphere packaging (CAP) or modified-atmosphere packaging (MAP), use of edible coating are the recent developments in the area of packaging.

However, besides being providing a protective atmosphere, packaging material itself may play an active role in enhancing the shelf life of product by nullifying the rate of deteriorative reactions, by arresting the growth of spoilage/pathogenic microorganisms. This has led to the concept of active packaging and Labuza first floated the idea. Other terms coined to denote such packaging include “smart” “functional” and freshness preservative packaging. Various kinds of active substances can now be incorporated into the packaging material to improve its functionality and give it new or extra function (Han, 2000). Such active packaging technologies are designed to extend the shelf life of foods, while maintaining their nutritional quality & safety.

2.0 HOW ACTIVE PACKAGING WORKS?

Active packaging technologies involve interactions between the food, the packaging material, and the internal gaseous atmosphere (Labuza and Breene, 1988). Diverse functions they perform include oxygen scavenging antimicrobial activity, moisture control, ethylene removal, ethanol emitting etc., the active component may be part of the packaging material or may be an inert or attachment to the inside of the pack.
Active packaging is designed to enhance the properties of packaging material so that it could increase shelf life of product. Therefore, the forms and applications of active packaging are diverse, addressing specific situations in the protection and presentation of foods and other products.

3.0 OBJECTIVES OF ACTIVE PACKAGING

Active packaging is selected to enhance the ability of conventional packaging to preserve the quality attributes of the product throughout the distribution system. However, the Rind of system used is based on following considerations.

- Shelf-life Extension
- Less expensive packaging materials.
- Simpler processing
- Easier handling
- Uniformity of packaging material
- Presentation

4.0 TYPE OF FOOD PRODUCTS SUITABLE FOR ACTIVE PACKAGING

Various kinds of food products, where active packaging technology has been found to have an important role in maintenance of quality and increase product life are discussed here.

4.1 Fruits and vegetables

Fruits and vegetables either fresh or minimally processed are vulnerable to microbial, attack and undergo unfavourable biochemical changes during storage. Though modified atmospheric packaging (MAP) is becoming more popular and has been found to increase the product life substantially. High CO\textsubscript{2} atmosphere slowed down the respiration process, and prevented the growth of aerobic microflora, but at higher level anaerobic metabolism as well as growth of anaerobic microorganisms, cause production of off-flavour compounds and pose health hazards to consumers. So active packaging systems with oxygen scavengers, CO\textsubscript{2} emitters, desiccants and antimicrobial compounds, may be proved beneficial. Ethylene production that accelerates the ripening and senescence, although suppressed in MAP at very high CO\textsubscript{2} concentration, but ethylene scrubbers with packaging material are an attractive alternative.

4.2 Meat and fish products

Besides being prone to microbial attack, meat, poultry and fish products are sensitive to oxidative changes. Low concentration of oxygen leads to the discolouration of meat colour as it causes oxidation of pink coloured nitrosomyoglobin. Moreover, water droplets that occur in the form of tissue fluid over the surface of fish, white or red meat provide a favourable breeding place for microbes.

Taints and off flavour in muscle foods is a common problem encountered during storage and transportation like moldy taints in fish shipment.
4.3 Cereals and snack foods

Cereal grains and their partially processed products such as flour, are low moisture content product and relatively more resistant to microbial as well as chemical changes. However, biological deterioration may result from insect infestations. Fluctuation in temperature and humidity enhance the rate of activity at various stages in the life cycles of insects. Worldwide opposition of chemical fumigants has left us with no other options but to look for real alternatives. Storage of grains at high CO\(_2\) environment proved effective in preventing insect growth and now in practice in European nations.

Fat present in grains and other processed products undergo chemical reactions, mainly oxidation causing off flavour production and decrease in nutritive value. Packaging in inert atmosphere or application of oxygen scavengers may solve the problem.

4.4 Dairy products

Dairy products especially cheeses owing to there higher water activity are susceptible to microbial growth. Sorbic acid impregnated cheese wraps has been in practice since long to prevent undesirable mold growth. Applying active packaging with scavengers can prevent oxidative changes in milk powders.

5.0 TYPES OF ACTIVE SUBSTANCES

Based on the nature of spoilage various kind of substances have been identified over the years to overcome these. However, only few of them can be applied in active packaging systems. These compounds/substances can be grouped into following categories:

5.1 Oxygen scavenger

Packaging films of various oxygen permeabilities can be used to control the oxygen levels in packs, but it requires precise data over the years about the product. The most promising active packaging systems are oxygen scavenging systems which absorb oxygen in the package and prevent oxidative changes (Ronney, 1981). Iron, platinum, ascorbic acid, and oxidizing enzymes such as alcohol oxidase, have been tested for their ability in various forms to control the oxygen. Effectiveness of iron is a function of water activity and as water activity decreases, the scavenging power also get reduced.

5.2 CO\(_2\) generating or scavenging

A complementary approach to oxygen control is to incorporate a carbon dioxide generating system into a film or add it as a sachet. Permeability of CO\(_2\) through plastic films is 3-5 times higher than the oxygen. Hence a generator is needed for some application. CaOH (slacked time) is most commonly used scavenger of CO\(_2\) and incorporated in number of formulations. The shelf life of ground fresh coffee tripled when a sachet containing iron powder and CaOH was
added in flexible bags. However, controlling the level of both O$_2$ and CO$_2$ may have some adverse effect on metabolic activity of fruits and vegetables.

5.3 Ethylene absorbent

Accumulation of ethylene in head space of packaging material, not only accelerate the ripening process, but also favour the formation of undesirable compounds like coumarin in carrots. Ethylene absorbing substances or as they commonly called ‘scrubbers’ include permanganates, metal catalysts and other physical adsorbents. Silica gel containing permanganate, which oxidize the ethylene has been successfully used for many fruit storage systems.

In DFRL Mysore, a permanganate based ethylene absorbing system has been developed and proved highly successful for storage of many tropical fruits and vegetables. A clay embedded in a film that scavenge ethylene is being developed in Japan.

5.4 Moisture scavenging

Water vapour formed during course of normal metabolism, create high humidity in package and allow the growth of molds and yeasts. A desiccant film or sachet can solve this problem. A film in the form of a pillow with entrapped propylene glycol placed in contact with meat or fish for several hours absorbs water and injures spoilage bacteria (Labuza, 1996). Silica gel, diatomaceous earth pad can be used for similar purpose.

5.5 Antimicrobial agents

Incorporation of antimicrobial agents into a polymer limits or prevents microbial growth. This application could be used for foods effectively, not only in the form of films, but also as containers and utensils, Antimicrobial activity may be incorporated from common antimicrobial substances, radiation, or gas emission/flushing. Most common one is chemical preservative, and though highly effective irradiation sterilization of food packaging material has not approved yet. Gas flushing in the form of CO$_2$ and sulphites, checked the growth of molds and yeasts in berries and grapes. However, there is no commercial material available that contains or releases sterilizing gases. Ethanol-vapour generating systems can inhibit mold growth especially in bakery products. (Smith et al., 1987). Antimicrobial packaging materials have to extend the lag phase and retard the growth rate of microorganisms to prolong shelf life and enhance food safety.

6.0 FORMS OF ACTIVE PACKAGING

The active components in packaging can exist either as part of an otherwise unmodified package or as an elaborate adjunct or design modification. Commercially available forms of active packaging systems are as follows:

6.1 Sachets

The major form in use at present is the insertion of sachets of various scavenger or emitters. Silica gel has been in use for protection of product from
water for many years. Sachets contain silica or lime based supporting material in which embedded other active components. Sachets are often kept between primary & secondary packaging. Commercially available sachets are presented in Table (1).

Table 1  Commercially available sachets

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Sachets</th>
<th>Components and Function</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ageless sachets</td>
<td>Reduced iron powder, salt and Trace ingredients, oxygen scavenger</td>
<td>Mitsubishi Gas Chemical Co., Japan</td>
</tr>
<tr>
<td>2.</td>
<td>Fresh max</td>
<td>Iron based oxygen scavenger</td>
<td>Multiforms Desiccant Inc.</td>
</tr>
<tr>
<td>3.</td>
<td>Ageless G</td>
<td>Ascorbic acid and sodium bicarbonate, CO₂ emitters</td>
<td>Tippan Printing Co.</td>
</tr>
<tr>
<td>4.</td>
<td>Ethicap</td>
<td>Grade alcohol (55%) Silica powder (35%) Ethanol emitters.</td>
<td>M/S. Freund Industrial Co. Ltd, Japan</td>
</tr>
<tr>
<td>5.</td>
<td>Sendomate</td>
<td>Palladium catalyst ethylene removal</td>
<td>Mitsubishi Gas Chemical Co. Japan</td>
</tr>
<tr>
<td>6.</td>
<td>Fresh keep</td>
<td>Activated carbon oxygen, ethylene, CO₂ scavenger</td>
<td>Kuroray Co. Ltd., Japan</td>
</tr>
<tr>
<td>7.</td>
<td>SO₂ Emitter</td>
<td>Sodium metabisulphite (microporous pad) inhibit mold growth</td>
<td>Alimentices Osku SA, Santiago.</td>
</tr>
</tbody>
</table>

6.2 Composite films

When active substance is incorporated along with packaging films, it diffuses slowly in headspace or migrates within the food product to perform specified function. Based on the activity desired to increase the shelf life of the product, certain kind of film have been developed.

6.2.1 Moisture control films

Moisture in package may be in the form of droplets (condensate) or as vapours. One of the simple form of such films include drip absorbent sheets made up of two layers of non-woven polyolefin, divided by heat seals into pouches containing polyacrylate super absorbent polymers. “Pichit” water absorbent sheets developed for wrapping food products in domestic refrigerator. It consists of an envelop of polyvinyl alcohol film sandwiching a glycol and carbohydrate in a strong water vapour absorber.

6.2.2 Oxygen scavenging films

Oxygen scavenging films or other plastic materials offers the opportunity to prevent oxygen ingress to the package by permeation as well as removing that originally present. They also offer the potential for package fabrication, filling and
sealing without the need for insertion or attachment of a sachet, commercially available films are rare in market. Bottles lid were developed with scavenging components and wide variations are available.

6.3.3 Antimicrobial films

Antimicrobial agents, fungicides and natural antagonists are applied to harvested produce in the form of aqueous dips or as waxes or other edible coatings. Synthetic zeolite called Zeomic, which has silver ions bonded into the surface layers of the pores. The zeolite is dispersed in a 3-5 μm thick polypropylene or polyethylene layer. Other kind of active packaging films are, ethylene absorbent, odour absorbent.

7.0 EDIBLE COATINGS AS ACTIVE PACKAGING MATERIAL

Edible films and coatings are thin continuous layers of edible material formed on or placed between food components to provide a barrier. These materials function as active packaging materials by providing more than traditional passive protection against the atmospheric and physical environments. To the extent they can provide additional protection by carrying antioxidants, antimicrobials, aromas, colours, etc. they are considered active and edible as well. Two major classes of film formers are, proteins and polysaccharides, for example, whey protein coatings and films can incorporate adequate amount of edible active agents as well as plasticizers. Future application may be found in carry antimicrobials to the surface of high moisture foods, retarting oxidation in intermediate moisture and low moisture foods and in maintaining the flavor profile of high aroma foods.

8.0 CONCLUSION

Active packaging is largely a series of innovation of the last two decades, there is still substantial amount of progress is going on. The introduction of active packaging requires re-appraisal of the normal requirement that there should not be any interaction between food product and packaging substances. It will have a wider application in future where emphasis is on minimally processed and reduced additive safe food products. Suitable designing, better understanding of interactions, safety and regulation through enforcement, will certainly enhance consumer’s faith in active packaging substances.

9.0 REFERENCES

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1.0 INTRODUCTION

The National Library in Dairying of the Institute was established in 1955 at Karnal consequent on the transfer of the Institute from Bangalore to Karnal. During the years, Library developed with the growth of the Institute. The National Library in Dairying collection comprises a choice collection of publication on Dairying, Animal Husbandry and related disciplines. Library has in stock of nearly 46,000 Books, 24,500 Bound Journals, 2500 Theses, 270 Microfiches, 2800 reprints, 6200 bulletins, and other miscellaneous publications. It also subscribes to over 650 periodicals of general and applied nature.

2.0 OPENING HOURS

The library remains open on all working days from 8.00 A.M. to 8.00 P.M. and 8.00 A.M. to 2.00 P.M. on Sundays and Gazetted holidays. Library shall remain closed on the three national holidays i.e. Republic Day, Independence Day and Gandhi Jayanti.

3.0 COMPUTERISATION

The National Library in Dairying has recently acquired BASISplus TECHLIBplus software package, which is an integrated multi-user library management system that supports all in-house operations of the library. The BASISplus TECHLIBplus consists of modules on acquisition, online cataloguing, circulation, serial, administrative function and maintenance.

Retrospective conversions of bibliographic record have been completed and 53,000 bibliographic records of documents in the library can be accessed through the TECHLIBplus. The database of books available in the library is being updated on day to day basis. New additions for the library are also updated regularly.

The TECHLIBplus package has been successfully implemented for the issue/return of documents, membership information, reservation of documents, statistical information and other circulation activities. Data entry work for serial system is in progress.

4.0 FACILITIES/SERVICES
• CD-ROM Database search services.
• Internet facility
• Reference Services
• Inter Library Loan Facility
• Document Supply Services
• Documentation Services
• Acquisition of Reading Material Service
• Circulation
• User Guidance Service

5.0 CD-ROM SEARCH

Large storage capacity of a CD-ROM enables it to store enormous quantity of information. Several abstracting and indexing services are available on CD-ROM in addition to their print version. CD-ROM databases contribute major role in effective research work in the field of science and technology. These databases can be accessed through WINSPIRS.

5.1 Searching CD-Rom using WinSpirs

WinSPIRS, Silver-Platter's search and retrieval software for Windows. The guide provides installation instructions and general information to start, use and exit SPIRS.

5.1.1 Introduction to WinSpirs

Silver Platter compact discs (CDs) contain one or more databases. A database is an organized collection of "records". Each record represents an article, book, conference, bibliographic citation, etc. Records are subdivided into categories of information known as "fields" such as title, author, etc. A database may be contained on a single CD or may be divided across two or more CDs.

WinSPIRS is Silver Platter’s search and retrieval software, operating in the Windows environment, that let's you search for information on Silver Platter CDs. You may control SPIRS by making choices from the pull-down menus, clicking buttons, and typing in dialog boxes. With WINSPIRS, you can search for records on specific subject keywords and display, print, or save those records. Search strategy, to use again in later sessions, may be saved.

5.1.2 Guide conventions

This guide uses the following conventions:

[F6] These brackets and typeface indicate a key on the keyboard
Search This boldface type indicates a WSPIRS button to click or command to execute
dyslexia This typeface indicate text as you would type it and
This boldface type indicates a WinSPIRS operator

5.1.3 WinSPIRS requirements

Below are the hardware and software requirements for using WinSPIRS.

4.1.3.1 Hardware

The minimum hardware requirements for WinSPIRS are:

- An IBM PC-compatible computer with a 80386sx processor
- 4 MB of RAM
- 8 MB or free hard disk space
- A monochrome VGA monitor (A color monitor is recommended)
- One high density floppy drive
- A Windows-compatible printer is recommended

4.1.3.2 Software

The minimum software requirements for WinSPIRS are:

- MS-DOS and PC-DOS version 3.1 or higher
- Microsoft Windows version 3.1 or higher
- MS-DOS CD-ROM Extensions version 2.1 or higher

5.2 Installation

- Insert the WinSPIRS Setup Disk 1 into the computer's floppy drive.
- If necessary, type ‘win’ at the DOS prompt to run Windows.
- From the Program Manager, choose ‘Run’ from the File menu.
- At the command line, type the drive name in which the WinSPIRS disk is located and the word setup, such as ‘a:setup’, and click OK (or press ‘Enter’)
- When the WinSPIRS Setup screen appears, click ‘continue’ to continue the installation. At this point, you can click ‘Exit’ to stop the setup program.
- The next dialog box displays a prompt asking you to confirm the subdirectory to install WinSPIRS to. Click ‘Continue’ again to accept the default subdirectory (C:\WINSPIRS), or type a new subdirectory and then click ‘Continue’. Alternatively, you can click ‘Back’ to review the setup process or Exit to stop the setup program.
- When prompted, insert the WinSPIRS Setup Disk 2 and click ‘OK’ to continue.

You may also want to add the WinSPIRS directory ‘c:\winspirs’ to the PATH statement so you can access WinSPIRS directly from the DOS prompt.

5.3 Startup
This section introduces you to the basics of WinSPIRS. Specifically, you will learn how to

- Start WinSPIRS
- Choose a database to search
- Understand the Main WinSPIRS screen
- Get help
- Use the Index, Thesaurus, and Automatic Subject Lookup
- Show, print, and download search results
- End a search session

Before you begin this section, you should have installed WinSPIRS on your computer. Refer to "Installing WinSPIRS" on page 2 for details.

As you proceed, refer to the online help for more details about any command or WinSPIRS concept.

5.4 Precautions

Before you start working with WinSPIRS, you should be familiar with general Windows techniques, such as how to move and resize windows and how to use the mouse. If you have any Windows-related question, see your Windows documentation. All references to mouse clicks refer to the left mouse button on a right-hand mouse unless otherwise specified.

You can start the WinSPIRS program in four ways:

- From a program group in Windows Program Manager
- With the 'Run' command in Windows Program Manager
- At the DOS prompt
- From the File Manager

Once you launch WinSPIRS, you then choose the database or databases you want to search.

5.5 Main screen

You perform searches and view the records retrieved by those searches on the Main WinSPIRS screen. There are three areas on the Main screen; the Search For: text entry area, the Search History area, and the Retrieved Records area. There are also six menus in the menu bar,

5.6 Getting help

There are several kinds of help available in WinSPIRS. You can get context sensitive help for screen areas and dialog boxes. By using the Help menu. You can get help on all menu items, on how to search, on basic WinSPIRS commands, or see a list of help topics from which you can choose. You can access database
guides- information specific to the database you are using - and you can even get help on how to use the help system.

5.7 Index

The Index displays an alphabetical list of terms used in the database. You can select terms from the Index and have WinSPIRS search for them.

5.8 Thesaurus

Many databases include a thesaurus, a list of controlled vocabulary terms used to ensure consistent indexing or records. With WinSPIRS you can look up terms in the thesaurus and find the preferred term for your topic.

Often, thesauri are organized hierarchically, from broad, general terms to more specific, narrow terms. You can use this feature of the thesaurus to focus a search by finding the most specific term for your topic, or to expand a search by searching for a broader term plus all of its more specific terms.

5.9 Search results

Once you have performed searches and retrieved records, you have several options, including showing, (Displaying) records, printing records, downloading records, and saving, search history. You can also mark specific records (by clicking the area around the record number), so that you can print, show, or download those particular records. You can output records in a variety of formats by changing the Show, Print, and Download options.

6.0 REFERENCES

1.0 INTRODUCTION

The word multimedia refers to the integration of multiple media such as visual imagery, text, video, sound and animation, which together can multiply the impact of your message. The integration of multimedia technology into the communication environment has the potential to transform an audience from passive recipients of information to active participants in a media-rich learning process. The introduction of multimedia or any other computer based information technology is not intended to substitute for a presenter. This new technology is rather intended to provide the presenter with a powerful tool that can greatly enhance communication\(^1\) by delivering a multi-sensory experience. However, a multimedia information kiosk\(^2\) or Internet Web site can be designed to provide information to users with or without human intervention.

Most of the advantages of multimedia manifest themselves in presentation applications. Earlier it was not easily possible to present large amounts of highly condensed information to an audience while retaining everyone's interest. However, with the advent of multimedia technology, it has now become possible as people see in color, focus on motion, and hear in surround sound. Multi-sensory presentations improve comprehension and hold the audience’s attraction.

2.0 DESKTOP MULTIMEDIA COMMUNICATOR

While using a computer-assisted presentation program, one must be able to differentiate among the four levels of presentations, viz., slide-presentations, multimedia presentations, interactive multimedia presentations and multimedia Internet Web sites.

- **Slide presentations**: These are linear presentations (one slide after another) developed using primarily text, graphics (clipart) and/or pictures. No interaction or branching (connection or linkages between different parts or sections of the presentation) is possible in this type of programs.
- **Multimedia presentations**: These presentations can be developed using text, graphics, charts, sounds, digitized video, computer animations and/or pictures in which no interaction between user and computer has been incorporated. The

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\(^1\) The exchange of ideas, messages, or information.
\(^2\) An automated information, data entry and transaction centres.
interaction, (exchange of ideas or messages) can take place between the presenter (communicator) and the audience.

- **Interactive multimedia presentations:** These presentations are developed with the same elements as those in the preceding category but incorporate built-in interaction between user and computer. This interaction can be in the form of data entry (entering alphanumeric answers), selection of possible answers or alternatives (multiple-choice or true/false questions), interaction with screen objects, requests and receipt of printouts, and other possibilities. This type of program format is appropriate for information kiosks, personnel training programs and computer-assisted education programs.

- **Multimedia Web pages:** This kind of presentation or application is initially developed using the aforementioned tools, but it needs to be compressed using specialized tools. These tools allow the application to be played back through a Web browser. These applications have the potential to become interactive by taking advantage of Web site hypertexting capabilities or by accessing databases external to the Web site.

### Presentation tools

<table>
<thead>
<tr>
<th>Name of software tool</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldus Persuasion</td>
<td>Adobe Systems Inc.</td>
</tr>
<tr>
<td>Astound</td>
<td>Gold Disk Inc.</td>
</tr>
<tr>
<td>Forshow</td>
<td>Bourbaki</td>
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<tr>
<td>IconAuthor</td>
<td>AimTech Corporation</td>
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<tr>
<td>ImageQ</td>
<td>Image North Technologies</td>
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<tr>
<td>Macromedia Director</td>
<td>Macromedia</td>
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<tr>
<td>Q/Media</td>
<td>Q/Media Software Corp.</td>
</tr>
<tr>
<td>MS-PowerPoint</td>
<td>Micro-Soft Inc.</td>
</tr>
<tr>
<td>Lotus Freelance Graphics</td>
<td>Lotus</td>
</tr>
<tr>
<td>Authorware Professional for Windows</td>
<td>Macromedia</td>
</tr>
</tbody>
</table>

### 3.0 CREATING MULTIMEDIA PRESENTATIONS

A computer-based presentation consists of a set of computer visuals that are designed to produce and deliver the relevant information to an audience. The visuals, also called slides can be pure text such as a list of bullets, a table of data, a graphic object like a bar chart, a drawing, or a scanned logo, etc. The modern multimedia presentation software provide us to create/import the data, organize these visuals into a presentation, sort them, include transition effects, and the ability to incorporate multimedia effects like audio, animation, and video into a presentation. The presentation is stored in a file that can be later edited. The presentation can be
played back on a computer monitor or projected onto a screen using a multimedia LCD projector to address a large audience like a class of dairying students.

3.1 Creating presentations with MS-PowerPoint

PowerPoint is a complete presentation graphics package. It can be used to produce a professional-looking presentation. It makes you an independent producer of your own high-quality presentations. When PowerPoint opens, you see the following startup dialog box:

Select the 'Blank presentation' and click 'OK' button. You will see the following slide layout menu showing various auto layouts.

Using a slide layout is an easy way to begin building a presentation. So, you select an appropriate layout and clicking 'Ok' button. Suppose you wish to prepare a title slide, then you should select the appropriate slide as shown along with its name in the above Auto Layouts box. You will see the following slide layout:
You can add the presentation title and sub-title at the designated places on the slide as shown above. Now suppose that you want to make a slide to hold some text as a list of bullets. Select the appropriate slide layout labeled ‘Bullets List’ in the Auto Layouts box through **Insert → New Slide** options on the toolbar. You will see the following slide:

Here, you can write the slide title along with other text for the slide. Similarly, you can prepare various slides which may incorporate text, graphic objects, and a combination of the two.

### 3.1.1 Saving a slide presentation

After preparing the slides you should save them in a presentation file through **File → Save As ...** options on the toolbar as follows:
From the above Color Scheme box you can select new colors for the background and text. You must choose the background color first, then a text color and then a combination of other colors to complete the new color scheme. Also, you can apply design templates provided by PowerPoint. On common task toolbar, click Format > Apply Design..., find and select the design you want to use or any presentation whose design you want to use and then click Apply button. The whole process is shown here under:

3.1.3 Create animated slides

You can use the Custom Animation command on the Slide Show menu to set all the animation effects you want for a slide. For example, you can set text to appear by the letter, a word, or a paragraph. You can have graphic images like scanned research photographs, logos (e.g., scanned Logo and photograph of Karan Fries cow of the NDRI are shown just below), drawings etc., and other objects such as charts and movies appear progressively, and you can even animate the elements of an object. You can also change the order in which objects appear on a slide, and you can set timings for each object. The whole process is shown in following image:

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4 To add a special visual or sound effect to text or an object. For example, you can have your text bullet points fly in from the left, one word at a time, or hear the sound of applause when a picture is uncovered. You can animate any number of objects on a slide, and you can even animate elements of a chart.
Also, sound and movie clips can be added from different sources like online Gallery, Internet, etc., to the slide through Insert Movies and Sounds options on the toolbar as follows:

3.1.4 Add transitions to a slide show

In slide or slide sorter view, select the slide or slides you want to add a transition to.

A special effect used to introduce a slide during a slide show. For example, you can fade in from black or dissolve from one slide to another. You can choose the transitions you want, and you can vary the speed of each.
On the **Slide Show** menu, click **Slide Transition**. In the **Effect box**, click the transition you want, and then select any other options you want. To apply the transition to the selected slide, click **Apply**. To apply the transition to all the slides, click **Apply to All**.

3.2 Playback a slide show
To play back (or view) the slide show, click **Slide Show** followed by **View Show** on the common toolbar as follows:

4.0 CONCLUSION
The applications of this software in the areas of teaching, research and extension education are enormous. Mostly in academics, we find it quite useful; teachers can create class-room presentations and students can create projects and presentations regarding their assignments, seminars etc. It can be further used for digitizing rare research photographs in order to preserve the important images and photographic information (i.e. creating a digital photo album) which can be shared with the students and others. Also, you can add voice to each and every slide to explain the context of the photograph. Once you run the slide show it will give you an impression as if you are watching a movie. Moreover, efforts can be made to develop automatic electronic slide shows which can demonstrate a newly developed technology, process or technique to the students/farmers/professionals working in industry, during dairy melas (i.e. carnivals) or the like forums. These are only a few
applications of the software, however, by stretching your imagination you can even find a lot more new practical applications.

5.0 REFERENCES

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INTERNET AND ITS RELEVANCE IN DAIRY RESEARCH

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1.0 INTRODUCTION

Internet is transforming lives of many people in the world. Internet is a computer-based worldwide information network. The Internet is composed of a large number of smaller inter-connected networks called Intranets. These intranets connect thousands of computers enabling them to share information with each other and to share various resources, such as powerful super computers, software's and databases of information. Internet has made it possible for people all over the world to effectively and inexpensively communicate with each other. On the Internet, each connected individual can communicate with anyone else across the globe, publish ideas, search literature on the relevant topic, or seek solutions to the problems from anywhere in the world with a minimum overhead cost. In the future, Internet may have a dramatic impact on higher education and business as more and more universities area-offering course and companies are offering courses and companies goods and services online.

2.0 HOW DOES THE INTERNET WORK?

Internet is based on the concept of a client-server relationship between computers, which is also known as client/server architecture. In this type of relationship, some computers act as servers, or information providers, while other computers act as clients, or information receivers.

To access information on the Internet, a user first logon (or connects) to the client computer's host network. A host network is a network that the client computer network is part of, and is usually a Local Area Network (LAN). Once the connection is established, the user requests for information from a remote server. If the information requested by the user resides on one of the computers on the host network, then that information is retrieved quickly and is sent to the user's terminal. However, if the information is on a server that does not belong to host LAN, then the host network connects to other networks until it makes a connection with the network containing the right server. In the process of connecting to other networks, the host may need to access a router, a device that determines the best connection path between networks and helps networks to make connections.

Once the client computer makes a connection with the server containing the requested information, the server sends the information to the client in the form of a file. A special computer program known as browser enables the user to view the file. Examples of Internet browsers are Internet Explorer, Netscape Navigator, and Mosaic, etc. Most of the Internet files are multimedia documents viz., text,
graphics, photographs, audio and video which are combined into a single document. The process of retrieving files from a remote server to the user's terminal is called downloading.

The important aspect of Internet is that it is structured around the concept of hypertext. The term hypertext is used to describe the interlinked system of documents in which a user may jump from one document to another in a non-linear, associative manner. By clicking on the hyperlink, the user is immediately connected to the document specified by the link. Multimedia files on the Internet are called hypermedia documents.

2.1 Accessing Internet

Access to Internet falls into two broad categories: dedicated access and dial-up access. In the dedicated access, the computer is directly connected to the Internet via a router, or the computer is part of a network linked to Internet. However, with dial-up-access, a computer connects to the Internet through a temporary connection generally over a telephone line using a modem - a device that converts the electrical signals from a computer into signals that can be transmitted over telephone lines. A modem is needed because computers are digital whose signals are made up of discrete units while most telephone lines are analog where the signals are continuous instead of discrete. A large number of companies called as Internet Service Providers (ISPs) are coming up and are providing dial-up access to the Internet at nominal fee. Examples of ISPs in India (national/international) are Satyam online, Dishnet DSL, Pacific Internet, Rediff, VSNL, etc.

2.3 Network addressing

In order to be a part of Internet, a computer must have a unique Internet Protocol (IP) network address so that the messages can be correctly routed to and from the machine over the Internet. Internet addresses are called Uniform Resource Locators (URLs). Some URLs are a string of numbers, which are difficult to remember, and therefore other conventions are used. Examples of this convention are http://science.msn.com. The http refers to hypertext transfer protocol, which is used to access particular location on the Internet. The name after the colon and double slash indicates the host name, which is the name of a specific computer system, connected to the Internet.

2.4 Electronic mail

The most widely used tool on the Internet is Electronic Mail (E-mail) which sends written messages between individuals or groups of individuals, often geographically separated by large distances, E-mail messages are generally sent from and received by mail servers - computers that are dedicated to processing and directing E-mail. Once a server has received a message, it directs it to the specific computer that the E-mail is addressed to. To send E-mail the process is reversed. E-mail has dramatically affected scientific, personal and business communication in a very convenient and inexpensive way.

Another use of E-mail is the Usenet, in which discussions on a particular subject are grouped together into newsgroups. There are thousands of newsgroups covering a wide range of subjects.
2.5 Use of Internet

From the late 1960s to early 1990s, Internet was a communication and research tool used almost exclusively for academic and military purposes. This changed radically with the introduction of the World Wide Web (WWW) in 1989. WWW is a set of programs, standards and protocols governing the way in which multimedia files are created and displayed on the Internet. Scientists and scholars are using Internet to communicate with colleagues, to perform research, to do on-line search of literature, to distribute course material and lecture notes to the students and to publish papers and articles. The Internet is also being used to access to complex databases and software which are useful for data analysis and drawing appropriate conclusions. Business firms and companies are using Internet to carry out commerce online (i.e., e-commerce), including advertising, selling, buying, distributing products, and providing after-sales service.

The use of E-mail over the Internet has also greatly speeded up communications between companies, among co-workers, and between other individuals. Media and entertainment companies are using Internet to broadcast audio and video, including live radio and TV programs; to have on line chat in which people carry on discussions using written text and to offer on line news and weather programs. There are very good examples where internet examples where Internet has been used to the advantage of farmer like in one situation where the farmers in Punjab could save the citrus crop from a deadly fungus by logging on to Florida University site as no local consultancy was available. Similarly a dairy farmer in Pondicherry village could save his only milch cow suffering from prolonged labor through a consultation with a veterinary surgeon over E-mail. The fishermen of local villages now go to seas only after downloading information from the US Navy's highly acclaimed weather Web site which provides information of even the height of waves and the speed and direction of winds.

2.6 Tips for effective search on the Internet

Many a times we end up wasting not only our precious time but also computer time following useless Uniform Resource Locators (URLs) which do not lead you to right place. In order to avoid this, you should know what you are looking for and how to get it. If you are looking for and how to get it. If you are looking for a broad subject, the best place to look for is a search-engine, which is in the form of a web directory and if something more specific is needed, then go to one of the specialized search engines. There are a large number of search engines available for surfing the net. The following table gives the list of search engines including Indian search engines that are available for faster and easier search of information.

<table>
<thead>
<tr>
<th>URLs of Search Engines</th>
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<tbody>
<tr>
<td><a href="http://www.yahoo.com">www.yahoo.com</a></td>
</tr>
<tr>
<td><a href="http://www.infoseek.com">www.infoseek.com</a></td>
</tr>
<tr>
<td><a href="http://www.altavista.com">www.altavista.com</a></td>
</tr>
<tr>
<td><a href="http://www.hotbot.com">www.hotbot.com</a></td>
</tr>
<tr>
<td><a href="http://www.opentext.com">www.opentext.com</a></td>
</tr>
</tbody>
</table>
2.6.1 Indian search engines

<table>
<thead>
<tr>
<th>URLs of Indian Search Engines</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://www.khoj.com">www.khoj.com</a></td>
<td><a href="http://www.123india.com">www.123india.com</a></td>
</tr>
<tr>
<td><a href="http://www.cyberindia.com">www.cyberindia.com</a></td>
<td><a href="http://www.sair.com">www.sair.com</a></td>
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<td><a href="http://www.indiaconnect.com">www.indiaconnect.com</a></td>
</tr>
<tr>
<td><a href="http://www.samachar.com">www.samachar.com</a></td>
<td></td>
</tr>
</tbody>
</table>

Some of the search engines are designed for specialized searches. These search for a particular topic only. For example, ‘dejanews.com’ is a search engine, which searches exclusively for newsgroups, ‘devsearch.com’ and ‘Netsearcher.com’ are search engines particularly for web developers and Internet professionals. ‘Flez.com’ is available for searching files on FTP sites and ‘mwsearch.com’ allows you to search within a number of medical sites.

Finding relevant data/information not only depends on search engines but also on the type of keywords you search for. In order to do an effective search, it is necessary to know about how search engines operate.

The basic approach followed in most of the search engines is that of relevance ranking. This means that the engine will present the results so that the first site on the list is considered the most relevant and the relevance decreases as we move down the list. The other consequence of relevance ranking is that there may be nothing on the web, which answers your query, but the search engine may still find a large number of results. This is because the search engines will not insist that all the keywords are present in the resulting Web sites. Even if a single word occurs in the Web site, that site will be brought back to you as a result. The first few results will hopefully contain all the keywords and may not always be the case and if no sites contain all the words then the best available will be presented as the most relevant site.
There are a number of ways in which you can narrow down your search. Boolean logic is one of the most common and effective ways and involves using AND, OR, NOT and parentheses for grouping. For example, "Indigenous" AND Dairy Products NOT Chhana based" will only list links containing Indigenous dairy products but exclude links regarding Chhana based dairy products. One can also use the "+" sign in the statements. For example "Indigenous + Dairy Products" will give more focused results than "Indigenous Dairy Products". Similarly one can use "-" sign to exclude certain words.

One can also give statements enclosed in quotes if it is desired to find pages where the words appear next to each other like in "job vacancies". Multiple words give more refined results than using a single word. Also, use similar words when you search the more synonyms, one gets the more chances of getting the results. Use of pipe key, i.e., '|', to refine the search results in a one-step search. For example, using "Cattle /Breeds" tells the search engine that the search is being made within the category of Cattle for the specific subject of breeds. If the multiple forms of a word are being searched, one can indicate it with a symbol for example wom*n. Search engines have different symbols for truncation. Most of the search engines offer their "advance search" where all these options are listed in pull down menus. All the search engines have help facility for users, which make it easy for novice to search information.

2.6.2 Offline search

Many a times we face the problem of 'Connection timed out' due to low bandwidth. Offline surfing speeds up browsing while saving on connect time and telephone bills. There are two ways in which one can browse and the other is to use a software utility. Both Internet Explorer and Netscape have off line browsing options. All the browsers have the files in a temporary folder. Internet Explorer 4 saves the pages visited by you in a temporary Internet files folder in the Windows directory. These files can be accessed even when you are off line. In Internet Explorer 4 one can enable this by selecting the "work offline" from the file menu and then type in a URL that has already been visited and thereafter its contents will be picked up and displayed from this folder. These utilities come in handy when multimedia heavy sites are being searched and take very long time to show on your browser.

2.6.2 A small tip for quick Internet surfing

Writing the complete Web site address repeatedly is boring and tiring and thus quite inconvenient. There is a simple trick which can make the task of opening sites much easier. If you use Internet Explorer for Web browsing, simply type the domain of an address, e.g., 'yahoo' and press Ctrl + Enter. Internet will automatically write 'http://www...com' around the name you typed that saves the botheration of writing those words repeatedly. For using this tip check whether the domain name is correct. If you are not sure about the domain name, you can simply write the name and press Enter. Internet Explorer will try to locate the site by using various extensions viz., .com, .org, .edu. etc. along with the domain name. Thus it helps substantially in writing down the Web address.
2.6.3 *Insecurity on the Internet*

The Internet has brought about several advantages and utilities, which one would not have even dreamt of a couple of years ago. It has provided opportunity for education, business, scientific research, entertainment, and much more. Persons from far-off continents and countries have been linked to each other as if they are next door neighbors and are able to exchange information and views within seconds, leaving aside all geographical and time zone barriers. But there is the other side of the coin too. Web transactions have negative aspects, which affect the activities. The most dangerous threats that the web users face today are hacking and virus, through the internet, which not only damages the Web sites but corrupts and changes the data stored even in the hard disk thereby causing downtime running into several hours or weeks.

3.0 **FUTURE OF INTERNET**

A major challenge facing the continued growth of the Internet is the difficulty of providing enough bandwidth to sustain the network. As Internet applications become more sophisticated and as more and more people around the world use Internet, the amount of information transmitted across the Internet will demand very high bandwidth connections.

India got caught into the 'World Wide Web' when Videsh Sanchar Nigam Limited (VSNL) launched the first full Internet Service for public access on 14th Aug., 1995. A five year old Internet Economy of our country has grown manifold from 1.7 lakh subscribers in Nov., 1998 to over 15 lakh subscribers by Aug., 2000. It is predicted that a mammoth 100 million Indians will be on the net with serious subscribers touching 40 million by Dec. 2003. The Internet industry in India employs 1.10 lakh people and by March, 2003, this number is likely to go up to 5 lakh people. For a significant number of people (73.4% of the net population), Internet is simply a means of communicating and for others it is a source of information with a hefty 77 per cent banking on facilities offered by search engines. Despite the phenomenal pace of the net growth and the projections for e-commerce, we still have a very long way to go. Bandwidth still remains a big issue, e-commerce and on line advertising has not picked up, PC penetration is low, Internet access is still not reaching the masses and security on the net continues to be a grave concern.

In order to overcome these infra-structural bottlenecks, a lot of companies are investing huge amounts of money in laying optical fiber network throughout the country, which will solve the connectivity problem in a big way. Also at least 12 private international gateways will be operational by March 2001 that will significantly improve the bandwidth problem in the country.
COMMUNICATION SKILLS FOR EFFECTIVE TRANSFER OF DAIRY PROCESSING TECHNOLOGIES

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1.0 INTRODUCTION

The term “Communication” stems from the Latin word “Communis” meaning common. In any social system, people communicate on many levels, for many reasons, with many people and in many ways. Various models, elements and processes of communication are often studied and discussed by scholars of social sciences. Over the last two decades special emphasis are being made by various institutions and organisations to communicate to a large number of people in a shortest possible time by using minimum resources of money and man power for disseminating information. To reach clientele with desired information pertaining to dairy industrial sector we have to be effective communicator, for which efficient skills are required.

Leagans (1961) defined communication as the process by which two or more people exchange ideas, facts, feelings or impressions in a way that each gains a common understanding of the meaning, intent and use of messages.

According to Rogers and Shoemaker (1971) communication is the process by which messages are transferred from a source to a receiver.

Ban and Hawkins (1988) defined it as the process of sending and receiving messages through channels which establish common meaning between source and a receiver.

2.0 DISCUSSION

In extension education communication mostly refers to the process of transferring an idea, innovation, research finding, technology or skill from one person to another accurately and satisfactory to bring out a desirable change.

Communication being a complex process having various elements can well be understood in the form of a model. Various communication models proposed by scientists and scholars are listed below:

2. Shanon and Weaver’s Model of Communication.
4. Lasswell’s Model of Communication.
5. Gerbner’s Model of Communication
6. Dance’s Helical Spiral Model of Communication.
7. Johnson’s Model of Communication
8. Westley and Machean Model of Communication.
10. Schramm’s Model of Communication.
12. Roger’s and Shoemaker’s Model of Communication.

These prevalent models of communication are either Linear or Circular. In most linear models, the most essential elements of communication process are the (1) Source (2) Message (3) Treatment (4) Channel (5) Receiver and (6) Effect, whereas, Barlund’s Transactional Model indicates that communication is a dynamic, continuous, circular, unrepeatable, irreversible and complex process. Dance’s Helical Spiral Model emphasizes that communication has no clear observable beginning and no clear observable end and the spiral continues indefinitely.

A Linear Model of Communication

It may be linear or spiral or circular communication model but all models essentially contains that an information with an intent is disseminated to a receiver using a channel. In the past four decades in the dairying sector systematic communication efforts have led to that India is producing more than 78 million tonnes of milk today as compared to 17 million tonnes in 1951. Various technologies developed in the dairy production fonts were communicated amongst the producers. Similarly in the dairy processing sector remarkable achievements have been made but still more is to be done to disseminate dairy processing technologies amongst the different clientele other than that of the organised dairy industrial sector.

3.0 TRANSFER OF DAIRY PROCESSING TECHNOLOGIES

Our efforts remained concentrated in transferring the dairy processing technologies to the organised dairy industrial sector where as the unorganised sector which handles comparatively more milk, remained un addressed. There are various dairy processing technologies which still need be disseminated amongst the different clientele who are engaged in dairy products making. A list of such available technologies based on their usage is shown in Table 1. Once these technologies are adopted by small scale dairy owners and ‘Halwais’ the different segments of the consumer population will then get the milk products worth the price paid.

In addition, in the rural areas the technologies for making different dairy products in different agro-ecological regions need be disseminated particularly amongst the rural women who for centuries are inheriting the traditional knowledge for making various dairy products. Indigenous Technical Knowledge (ITK) used by dairy farmers in different agro-ecological regions of the country has been considered as an important area in the dairy production fronts and a few research studies have also been conducted in this area. Where as, in the area of dairy processing no such serious attempt has been made to study and document the various dairy processing methodologies prevalent in the rural areas particularly amongst the rural women who
are engaged in milk processing for making different dairy products. ITKs prevalent in
different socio-cultural settings of the country can direct us in our research
endeavours to re-refine the prevalent ITKs of dairy processing so that the dairy
products formulated in the rural sector can have better quality, taste, flavour, shelf
life etc.

**Table 1 Technologies developed on different dairy products/processes by the
dairy technology division**

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Relevance to different clientele</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Milk Shake Mix Powder</td>
<td>RW X DW X HW X</td>
</tr>
<tr>
<td>2. Gulab Jamun Mix Powder</td>
<td>RW X DW X</td>
</tr>
<tr>
<td>3. Sterilized Cream</td>
<td>RW X DW X</td>
</tr>
<tr>
<td>4. Lassi</td>
<td>X</td>
</tr>
<tr>
<td>5. Khoa Powder</td>
<td>RW X DW X</td>
</tr>
<tr>
<td>6. Manufacturing of Yoghurt</td>
<td>RW X X X</td>
</tr>
<tr>
<td>7. Resogolla Mix Powder</td>
<td>RW X X X</td>
</tr>
<tr>
<td>8. Instant Kheer Mix</td>
<td>RW X X X</td>
</tr>
<tr>
<td>9. Acidophilus Milk</td>
<td>RW X X X</td>
</tr>
<tr>
<td>10. Dahi from Sweet Cream Butter</td>
<td>RW X X X</td>
</tr>
<tr>
<td>11. Acido-whey Soft Drink</td>
<td>RW X X X</td>
</tr>
<tr>
<td>12. Shrikhand</td>
<td>RW X X X</td>
</tr>
<tr>
<td>13. Paneer</td>
<td>RW X X X</td>
</tr>
<tr>
<td>15. Sandesh</td>
<td>RW X X X</td>
</tr>
<tr>
<td>16. Packaging of Khoa and Chhana</td>
<td>RW X X X</td>
</tr>
<tr>
<td>17. Sweet Cheese</td>
<td>RW X X X</td>
</tr>
<tr>
<td>18. Surti Cheese</td>
<td>RW X X X</td>
</tr>
<tr>
<td>19. Ricotta Cheese</td>
<td>RW X X X</td>
</tr>
<tr>
<td>20. Mozzarella Cheese</td>
<td>RW X X X</td>
</tr>
<tr>
<td>21. Gouda Cheese from Buffalo Milk</td>
<td>RW X X X</td>
</tr>
<tr>
<td>22. Swiss Cheese</td>
<td>RW X X X</td>
</tr>
<tr>
<td>23. Increasing the Shelf-life of Ghee</td>
<td>RW X X X</td>
</tr>
<tr>
<td>24. Low Fat Spreads</td>
<td>RW X X X</td>
</tr>
<tr>
<td>25. Coffee Complete</td>
<td>RW X X X</td>
</tr>
<tr>
<td>26. Mango Milk Powder</td>
<td>RW X X X</td>
</tr>
<tr>
<td>27. Whey Protein Concentrate</td>
<td>RW X X X</td>
</tr>
<tr>
<td>28. Whey Powder</td>
<td>RW X X X</td>
</tr>
<tr>
<td>29. Low Lactose Powder</td>
<td>RW X X X</td>
</tr>
<tr>
<td>30. Soft Serve Ice-Cream From</td>
<td>RW X X X</td>
</tr>
<tr>
<td>31. Accelerated Ripening of Cheese</td>
<td>RW X X X</td>
</tr>
</tbody>
</table>

= Technologies applicable for specific client
X = Technologies applicable for dairy industry

RW = Rural Women, DW = Small Scale Dairy Owners, HW = ‘Halwais’
It will also help in identifying indigenous dairy products popular in a particular region for mechanisation and scaling up these techniques based on scientific rationale. With the changing global scenario under the WTO we have to evolve effective communication strategies right from production of quality milk under diversified field situations prevalent in the country up to its processing so that ultimately the milk products made are competitive in the global market.

For effective transfer of dairy processing technologies amongst the organised and un-organised sector let us examine the process. The technology development, treatment, assessment and transfer are dynamic, continuous, sequential and complex processes. Transfer of technology (TOT) usually means movement of information/inputs from a research (source of technology generation) or an innovation system through an extension system (which acts as interpreter and disseminator) to the clientele (users of technology) system. A simple model of TOT has been shown in Fig. 1.

Once a technology is considered to be proven and ready to be disseminated in the client system various communication skills are employed and used by extension functionaries or even by subject-matter specialists of various disciplines. In most cases, we take it for granted that the ‘proven technology’ of a research system will fit into the client system which is not always true with the result poor adoption rates are reported for various recommended/disseminated technologies.

It is first and foremost that technological finding be seen from the different angles of clientele system’s perspective and then various communication methods be selected for its dissemination. Prior to selection of the various available methods of communication, the communicator or the source should be thorough about the communication process and should develop and attain communication skills for efficient TOTs.

4.0 COMMUNICATION SKILLS

To make any communication process effective, a communicator should possess the following skills.

- Identifying his professional abilities and limitations.
- Knowing in advance his audience (clientele) – their needs, interests, abilities etc.
- Selecting technology, research finding, innovation or message – its content, validity, usefulness and importance.
- Treatment of message.
- Expressing message- verbal and written.
- The selection and use of channels that will reach the audience, their usefulness and limitations.
- Ascertain ing feed-back.
In verbal communications every communicator is expected to have acquired and attained the best skills. It is expected that the communication skills possessed by the communicator make him/her capable in most communication situations to present to a few basic ideas in the allotted time. To many ideas at one time are confusing. Be responsive to the audience, don’t look like as if you are reading or talking, modulate your voice tones, stress on sentences required at certain junctures be practised, do not act down to the clientele group you are communicating. Effective verbal communication requires sincerity, smoothness, warmth, enthusiasm, flexibility and appropriateness of voice, gestures and movements.

For faster TOT using written material, communicator should attain skills in designing and developing posters, folders, booklets, bulletins etc. Various colour schemes, layouts, photographs, size of the printed literature, its friendly readability, the kind of impact expected on the reader etc. are of utmost importance which leads to effective communication of dissemination of information.

Use alternative communication methods when appropriate, as in group discussions, photographs, panels, graphics, video-film, LCD projections etc. Plan the use of these methods in advance. Audio-visual and other instructional devices be used for making communication effective for faster TOT.

Once a communicator considers the above communication delicacies, the message pertaining for TOT will be faster, received quicker by the audience with the intended meaning and will be adopted at a faster rate as compared to a poorly planned communicated message.

5.0 REFERENCES

1.0 INTRODUCTION

The safety and stability of the product during its whole shelf-life are major concerns of dairy and food industry. Modern consumer trends and food legislation have made it increasingly critical to attain these objectives. Hygienic irrevocability of milk and milk products is considered as a guarantee of safety. These products are considered hygienically irrevocable (pure) when they are:

- free of agents of zoonoses (diseases transmissible from animals to humans and vice versa) and alimentary diseases.
- free of ecological polluters and drugs in quantities not higher than prescribed tolerances.
- not radiologically contaminated above the allowed level of contamination.
- not sensorily changed to a degree for human consumption.

Microbiological norms for milk and milk products as stated in the statute (4) of USA are provided in Table.

<table>
<thead>
<tr>
<th>Food Stuff</th>
<th>Salmonella Spp.</th>
<th>Coagulase Positive Staphylococci</th>
<th>Sulphite-reductive Clostridia</th>
<th>E. Coli</th>
<th>Proteins</th>
<th>Total count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk</td>
<td>Neg in 25 ml.</td>
<td>Neg . in 0.01 ml</td>
<td>Neg . in 0.01 ml</td>
<td>Neg . in 0.001 ml</td>
<td>Neg . in 0.001 ml</td>
<td>100,000/ml</td>
</tr>
<tr>
<td>Pasteurized milk in a Dairy</td>
<td>Neg . in 25 ml</td>
<td>Neg . in 1 ml</td>
<td>Neg . in 1 ml</td>
<td>Neg . in 1 ml</td>
<td>Neg . in 1 ml</td>
<td>30,000/ml</td>
</tr>
<tr>
<td>Intrade</td>
<td>Neg . in 1 ml</td>
<td>Neg . in 0.1 ml</td>
<td>Neg . in 0.1 ml</td>
<td>Neg . in 0.1 ml</td>
<td>Neg . in 0.1 ml</td>
<td>100,000/ml</td>
</tr>
<tr>
<td>Dried milk</td>
<td>Neg . in 25 g</td>
<td>Neg . in 0.1g</td>
<td>Neg . in 0.01 g</td>
<td>Neg . in 0.1g ml</td>
<td>Neg . in 0.1g</td>
<td>50,000/g</td>
</tr>
<tr>
<td>Hard cheese</td>
<td>Neg . in 25 g</td>
<td>Neg . in 0.1g</td>
<td>Neg . in 0.1g</td>
<td>Neg . in 0.1g</td>
<td>Neg . in 0.1g</td>
<td>-</td>
</tr>
</tbody>
</table>

Consumers are distinctly exhibiting their marked preference for high quality, preservative-free, mildly treated safe food with extended shelf-life. As manufacturers commonly resort to acidity and heat treatments to control the proliferation of pathogenic and spoilage microflora, the innovative approaches for preservation are
need of the hour to meet the legal requirement as well as consumers aspirations e.g. mild heating, high hydrostatic pressure, ultrasound, pulsed light, microwave, Ohmic treating, pulsed electric field etc.

- Various chemico-physical methods of food preservation are designed and intended to put microflora of food in a microbial stress by creating unfavourable environmental conditions (non-optimal temp. acidic, salted or dry medium, oxygen or nutrient starvation) and by damaging cells (heating, freezing drying etc.). Former situation simply calls for a biochemical response adaptation while in the latter case only partially damaged cells will be able to grow and form colonies in a recovery medium.

Therefore, the efficiencies of various inactivation and preservation methods are required to be assessed with regard to enormous potential of food pathogens and spoilers to adapt to a wide variety of stress conditions (e.g. cod shock, heat shock, acid stress, osmolarity-stress, and high hydrostatic pressure-stress).

Microorganisms have evolved very sophisticated responses to adapt to environmental changes and to survive under stress conditions leading to activation/or repression of a number of genes to adapt cell physiology or metabolism to new conditions. These defence systems can be broadly divided into two classes as follows:

- The first class comprises specific systems which are induced by sublethal doses of a chemical or physical stress and permit survival against challenge dose of the same agent.
- The second class consists of more general systems which prepare cells to survive towards very different environmental stresses without the need for cultures to have had prior exposure to them. These systems are inducted in stationary phase under starvation conditions and sometimes also in hyperosmotic environments.

This lecture deals with the resistance responses of microorganisms towards preservation methods commonly employed.

2.0 CHEMICAL PRESERVATIVE AGENTS

2.1 Weak organic acids

The common acids used for preservation are acetic, lactic, benzoic and sorbic acid. These acids can remain present in the environment as a result of fermentation or alternatively as preservatives.

Microbial resistance to weak organic acids can manifest through various mechanisms as described in following sections:

- Presence of Outer cell Membrane Resistance to weak organic acids can be conferred by innate structural features of a microorganism such as an impermeable outer membrane that acts as a structural barrier. Gram-positive bacteria lack such an outer membrane and hence are susceptible to such agents. On the contrary, gram-negative bacteria possess an inner and outer
membrane. The latter with a thick lipopolysaccharide layer has a well established role in modulating the accessibility of a cell to preservative and other small molecules.

- Production of inactivator In some cases, microorganisms have been reported to degrade weak acids by making use of specific enzymes. Such an enzymatic degradation of sorbic acid to pentadien by fungi is common.

- Inducible Resistance Mechanisms - This aspect has attracted a lot of interest among researchers in recent years. *S. typhimurium, E. coli 0157:H7, Shigella flexneri* and *L. monocytogenes* are basically neutrophils. These microorganisms may be exposed to dramatic pH fluctuations in nature e.g. in foods and during pathogenesis. These bacteria are known to possess an acid tolerance response (ATR) consisting of a complex defence system that allows cell to survive pH values as low as pH 3.0 (during passage through gastrointestinal tract).

- The ATR is induced by prior exposure of an organism to sublethal pH conditions. This can experimentally be achieved by exposing exponential phase cells to a sublethal pH for sufficient time to allow synthesis of Acid Shock Proteins (ASPs) that protect the cells against the otherwise lethal acid pH. The function of ASPs is the prevention and/or repair of acid-induced damage to macro-molecules.

- Low pH induces
  - several aminoacid decarboxylase
  - accumulation of RpoS, PhoP and Fur that control distinct sets of ASPs.
  - Down regulation of Membrane ATPase

- The resistance of spoilage yeasts to weak organic acid is known to depend on the H⁺ - pumping P-type membrane ATPase. Long-term stress response of yeasts involves the induction of an integral membrane protein Hsp³⁰ which down regulates the increased activity of the membrane ATPase to conserve cellular energy pools which otherwise be consumed by the enzyme attempting to restore homeostasis.

- Efflux of anions

- Studies have indicated the presence of a membrane located multidrug resistance pump Pdr 12 in yeast cells which removes accumulated anions from inside the cells. This action of simply pumping anions out of the cell would create a futile cycle where the anions re-associate at the lower external pH and reenter the cell. However, recent studies have demonstrated that adapted yeasts reduce the diffusion coefficient of preservatives across the plasma membrane such that passage of weak acids into the cell is reduced. Therefore, efflux of protons and anions by the H⁺ -ATPase and Pdr12 respectively would not create a futile cycle if there is a concurrent reaction in the ability of the compounds to diffuse across the cell membrane and enter the cytosole.

### 2.0 HYDROGEN PEROXIDE

In dairy industry H₂O₂ has been used to preserve raw milk, whey and for the decontamination of packaging material. It has also been successfully used in food
processing to preserve corn starch, dried eggs and decontamination of fruit, vegetable and raisin.

Microorganisms protect themselves against H\textsubscript{2}O\textsubscript{2} in a number of ways. Yeasts are equipped with following primary antioxidant defences against the application of H\textsubscript{2}O\textsubscript{2}.

- Production of glutathione, a key to reduction of protein disulfide, scavenging of free radicals etc.
- Production of H\textsubscript{2}O\textsubscript{2}, oxidized glutathione, NADP\textsuperscript{+} to NADPH.
- Dismutation of superoxide anion
- Decomposition of H\textsubscript{2}O\textsubscript{2}.
- Binding of Cu, prevention of Fenton reaction, scavenging superoxide and hydroxyl radicals.

Bacteria, unlike yeasts are not known to have exhaustive defence mechanisms. Most of them depend on the catalase activity to degrade toxic levels of H\textsubscript{2}O\textsubscript{2}. Nevertheless, high diffusion rate of H\textsubscript{2}O\textsubscript{2} into the cell ensures damage of cells. However, in high density populations catalase positive cells produce enough enzyme to protect most of the population against killing of H\textsubscript{2}O\textsubscript{2}. A small acid soluble proteins of the α / β type synthesised in the developing spores has been shown to protect the DNA in the dormant bacterial spore against damage.

3.2 Lytic enzymes

Lytic enzymes are essentially cell wall perturbing entities. Such biomolecules e.g. Lysozyme have been commonly used as food preservative. Gram positive bacteria lacking outer membrane are the most vulnerable to lytic action. The combination of lysozyme hydrolyzing the bacterial cell wall, nisin, perturbing the membrane by electroporation mechanism and the chelator citrate is very effective against gram positive bacteria, \textit{L. monocytogenes} and \textit{L. innocua}. Gram negative bacteria can be sensitised to the action of lysozyme by adding EDTA.

The resistance development by target microflora proves detrimental to use of antimicrobials. A number of recent reviews have provided insight into the response of yeast cells towards inhibitory factors. Yeast cells are reported to initiate a sequence of enzymatic reactions known to transmit the detection of attack on cell wall to the nucleus. It triggers:

- increased chitin synthesis
- enhanced expression of an alternative B1, 3-glucan synthase (FKS\textsubscript{2})
- enhanced incorporation of at least one cell wall protein, CwpIp

3.0 PHYSICAL METHOD

Physical applications employed to preserve food include temporary increases in the product's energy level (heating, irradiation), controlled reduction of the
product's temperature (Chilling, freezing) controlled reduction in the product's, water content (concentration, drying) and the use of protective packages.

3.1 Heat treatment

Treatment of dairy as well as other food products at elevated temperature (blanching, pasteurization, sterilization) is a common process of food preservation. Thermal processes can be applied through various means such as water, steam, hot air, electrical, light, ultra sound or microwave energy.

Bacterial thermotolerance is affected by a number of factors. It is shown to be boosted upon exposure to sublethal heating temperature, viral infections and chemical compounds such as ethanol, methylating agents, antibiotics and amino acid restrictors. Protection may be achieved through:

- Accumulation of osmolytes known to enhance protein stability and protect enzymes against heat activation.
- Synthesis of Heat Shock Proteins (HSPs)
- Production of spores

Heat Shock Proteins - Upon exposure to sub-lethal temperatures bacterial cells are shown to be producing a set of heat shock proteins. They include chaperones and proteases jointly responsible for maintaining quality of cellular proteins. Both types of enzymes have as their substrate a variety of misfolded and partially folded proteins that arise from slow rates of folding or assembly, chemical or thermal stress, intrinsic structural instability and biosynthetic errors. These enzymes recognize inactive, non-active or unstable proteins leading to degradation of the proteins to smaller peptides or formation of active, native and/or stable proteins respectively at the expense of ATP. The primary function of classical chaperones Dnak (HSP 70) and its cochaperones Dnaj and GrpE and GroEL and its cochaperone GroEs is to modulate protein folding pathways thereby preventing misfolding and aggregation and simultaneously promoting refolding and proper assembly. HSPs are reported to be induced by several stress situations e.g. heat, acid and macrophage survival suggesting their contribution in bacterial survival during infection. Besides HSPs may facilitate the survival of pathogenic microorganisms in foods during exposure to lethally temperatures. In *E. coli* the heat shock response to temperature up shift from 30°C to 42°C consists in the rapid upto 15-fold induction of synthesis of 20 HSPs followed by an adaptation period/where the rate of HSP synthesis decreases to reach a new steady-state level.

3.2 Osmotic stress

Hyperosmotic pressure produced by lowering of water activity ($a_w$) is one of the most widely used means of food preservation Desiccation (evaporation/condensing/drying) or addition of high amounts of osmotically active compounds e.g. salts and sugars lowers the $a_w$ of the food.

The most common response to hyperosmotic shock is the cytoplasmic accumulation of a certain class of solutes called 'Compatible Solutes'.
Examples of 'compatible solutes' are betaine, carnitine, trehalase, glycerol, sucrose, proline, mannitol, glucitol, ectoine and the small peptides. Common food pathogens, *E. coli* 0157:H7, *S. typhimurium*, *B. subtilis*, *L. monocytogenes* and *Staphylococcus aureus* adapt to osmotic stress commonly by the accumulation of betaine (N, N, N-trimethylglycine) via specific transporters. *E. coli*, *B. subtilis* and *S. aureus* are also capable of synthesizing betaine from exogenously provided choline.

### 3.3 Low temperature

The increased employment of low temperature for preservation of food has been necessiated in recent years for a variety of reasons as follows:

- growing popularity of fresh or minimally processed food, often preservative free
- long time interval between production and consumption and
- extended use of refrigerators

In the present context, food borne psychrotrophic pathogens such as *L. monocytogenes*, *Yersinia enterocolitica*, *B. cereus* and *Clostridium botulinum* show a wide variety in minimum growth temperatures and hence are a major concern. The increased use of freezing as a preservation method has led to a keen interest in microbial adaptation to freezing conditions.

Microbial resistance that permit growth at low temperature involve following mechanisms.

#### 3.3.1 Synthesis of cold-shock proteins

Microorganisms exhibit their tolerance to an abrupt decline in growth temperature (cold-shock). Many bacteria synthesize increased amounts of small (7KDa) proteins known as cold shock proteins (CSPs) upon a sudden decrease in temperature. These CSPs are known to share a high degree of similarity (> 45%) in a variety of gram-positive and gram-negative bacteria including food related microorganisms like *E. coli*, *B. subtilis*, *B. cereus*, *Salmonella enteritidis*, *S. typhimurium*, *L. lactis* and *L. plantarum*. Not all bacteria synthesize such CSPs e.g. *Helicobacter pylori* and *Campylobacter jejuni*. The most exhaustively studied CSPs are of *E. coli* (CspA<sup>E</sup>) and *B. subtilis* (CspB<sup>B</sup>). Both have the ability to bind single stranded DNA and RNA and are reported to be involved in protein synthesis and mRNA folding. Csps restore the structure of mRNA disrupted at low temperature and thus facilitate the smooth protein synthesis.

The cold-shock of *E. coli* induces an additional specific set of ~ 15 proteins known to play role in various cellular processes e.g. Nus A (termination and antitermination of transcription), RecA (recombination and SOS response), H-NS and Gyr A (DNA-supercoiling) polynucleotide phosphorylase (mRNA degradation). Similarly *B. subtilis* responds to cold-shock by inducing a set of about 37 proteins involved in various cellular processes e.g. Chemotaxis, sugar uptake, translation, protein folding and general metabolism.
DNA supercoiling- The alteration in growth temperature leads to modification in DNA supercoiling (e.g. negative supercoiling) in which DNA topoisomerase and DNA gyrase activity play an essential role for the transduction of the environmental signal to bacterial nucleoid.

3.3.2 Membrane adaptation response

Microorganisms modify their membranes in order to maintain their fluidity at low temperature. A decrease in growth temperature is accompanied by an increase in the proportion of shorter and/or unsaturated fatty acids in the lipid. It results in the modulation of the activity of intrinsic proteins that perform functions such as ion pumping and nutrient uptake. It is believed that the transcription of the genes involved in unsaturated fatty acid synthesis is regulated by a promoter(s) that is activated upon an increase in negative supercoiling caused by a temperature downshift.

Compatible solutes (betaine, proline, carnitine) may play a role in osmoprotection and in cold adaptation. The mechanism behind this cryoprotective effect of compatible solutes remain to be elucidated. Sublethal low temperature treatment may provide protection to psychrotrophs during subsequent freezing and result in a high survival rate of bacteria in frozen food products. Low temperature adapted bacteria are known to exhibit shorter lag times at cold temperature and their higher growth rate may be critical to food quality and safety. An understanding of cold adaptation’s mechanism is necessary to develop methods to control the growth of psychrotrophic microorganisms offering a shelf-life as well as safety hazard in the context of refrigerated foods.

3.4 High hydrostatic pressure

High Pressure Processing (HPP) also referred as high hydrostatic pressure (HHP) or Ultra High Pressure (UHP) processes is applied to liquid and solid foods with or without packaging to pressure between 100 and 800 Mega Pascals at process temperature ranging from 0° to 100°C. This treatment acts instantaneously and uniformly throughout a mass of food irrespective of size, shape and food composition. High hydrostatic pressure techniques are being commercially used in France, Spain, USA, Mexico and Japan.

The barotolerance has been observed in a number of studies. It is proposed that exposure of bacteria to high hydrostatic pressure induces a unique stress response resulting in formation of high levels of CSPs and HSPs and other proteins. Further those compounds that improve membrane fluidity are found to impart resistance to the organism against pressure. One such compound identified in barophilic bacteria is doco’sahexaenoic acid.

4.0 CONCLUSION

Bacteria that develop resistance to food preservatives and processes represent a grave concern in the food industry. Many microorganisms show tolerance to disinfectants e.g. chlorine and Quaternary Ammonium compounds commonly used in dairy and food industry for the purposes of cleaning and sanitizing.
equipments and environment. Synthesis of shock proteins, change in lipid composition of microbial cell membrane and acquisition of plasmid are some of the factors found responsible for imparting resistance towards a wide spectrum of environmental shocks. Application of a particular stress may also help microorganisms to acquire a cross tolerance. Such microbial responses would pose a serious threat to long time preservation of food products and manufacture of minimally processed foods. Environmental stresses have the potential not only to modulate the survival of spoilage microorganism but also the virulence of microbial pathogens. Cellular adaptive responses to environmental stresses play a key role in potentiating the pathogenicity of food borne pathogens.

5.0 REFERENCES