

# Entrepreneur India

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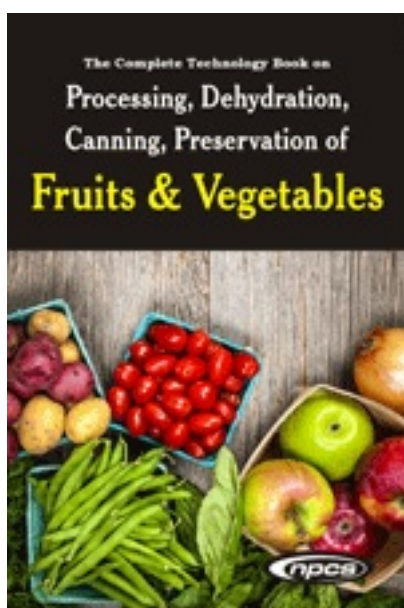
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The Complete Technology Book on Processing,  
Dehydration, Canning, Preservation of Fruits & Vegetables (3rd  
Revised Edition)



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Fruits and vegetables are important sources of vitamins, minerals and dietary fibre. The consumption of fruits and vegetables has increased significantly as consumers have become more health-conscious. Whilst most fruit and vegetables should be eaten fresh, processed fruit and vegetables can be acceptable alternatives. Fruit and vegetables have many similarities with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. Processing (canning, Dehydration & Preservation) increases the shelf life of fruits and vegetables.

Fruits and vegetables are processed into a variety of products such as juices and concentrates, pulp, canned and dehydrated products, jams and jellies, pickles and chutneys etc. The extent of processing of fruits and vegetables varies from one country to another. The technology for preservation also varies with type of products and targeted market. Owing to the perishable nature of the fresh produce, international trade in vegetables is mostly confined to the processed forms.

India is the second largest producer of fruits & vegetables in the world with an annual production of million tonnes. It accounts for about 15 per cent of the world's production of vegetables. Due to the short shelf life of these crops, as much as 30-35% of fruits and vegetables perish during harvest, storage, grading, transport, packaging and distribution. Hence, there is a need for processing technology of fruits and vegetables to cater the domestic demand.

The major contents of the book are procedures for fruit and vegetable preservation, chemical preservation of foods, food preservation by fermentation, preservation by drying, canning fruits, syrups and brines for canning, fruit beverages, fermented beverages, jams, jellies and marmalades, tomato products, chutneys, sauces and pickles, vegetables preparation for processing, vegetable juices, sauces and soups, vegetable dehydration, freezing of vegetables etc. The book also contains photographs of Production Line & Machinery.

It will be a standard reference book for professionals, entrepreneurs, food technologists, those studying and researching in this important area and others interested in the field of fruits and vegetables processing.

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# **General Properties of Fruits and Vegetables; Chemical Composition and Nutritional Aspects; Structural Features**

## **General properties**

Fruits and vegetables have many similarities with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. In fact, many vegetables may be considered fruit in the true botanical sense. Botanically, fruits are those portions of the plant which house seeds. Therefore, such items as tomatoes, cucumbers, eggplant, peppers and others would be classified as fruit on this basis.

Vegetables are derived from various parts of plants and it is sometimes useful to associate different vegetables with the parts of the plant they represent since this provides clues to some of the characteristics we may expect in these items. A classification of vegetables based on morphological features as seen in Table 1.

Fruit as a dessert item is the mature ovaries of plants with their seeds. The edible portion of most fruit is the fleshy part of the pericarp or vessel surrounding the seeds. Fruit in general is acidic and sugary. They commonly are grouped into several major divisions depending principally upon botanical structure, chemical composition and climatic requirements.

## **Chemical Composition**

### **1. Water**

Vegetable cells contain important quantities of water. Water plays a vital role in the evolution and reproduction cycle and in physiological processes. It has effects on the storage period length and on the consumption of tissue reserve substances.

In vegetable cells, water is present in following forms :

I bound water or dilution water which is present in the cell and forms true solutions with mineral or organic substances;

I constitution water, directly bound on the chemical component molecules and which is also removed with difficulty.

Vegetables contain generally 90-96% water while for fruit normal water content is between 80 and 90%.

### **2. Mineral substances**

Mineral substances are present as salts of organic or inorganic acids or as complex organic combinations (chlorophyll, lecithin, etc.) they are in many cases dissolved in cellular juice.

Vegetables are more rich in mineral substances as compared with fruits. The mineral substance content is normally between 0.60 and 1.80% and more than 60 elements are present; the major elements are: K, Na, Ca, Mg, Fe, Mn, Al, P, Cl, S.

Even if its content in the human body is very low, iron (Fe) has an important role as a constituent of haemoglobin. Main iron sources are apples and spinach.

Salts from fruit have a basic reaction; for this reason fruit consumption facilitates the neutralisation of noxious uric acid reactions and contributes to the acid-basic equilibrium in the blood.

### **3. Carbohydrates**

Carbohydrates are the main component of fruit and vegetables and represent more than 90% of their dry matter. From an energy point of view carbohydrates represent the most valuable of the food components; daily adult intake should contain about 500 g carbohydrates

Some properties of sugars. Sugars such as glucose, fructose, maltose and sucrose all share the following characteristics in varying degrees, related to fruit and vegetable technology :

I they supply energy for nutrition;

I they are readily fermented by micro-organisms;

I in high concentrations they prevent the growth of micro-organisms, so they may be used as a

preservative;

On heating they darken in colour or caramelize;

Some of them combine with proteins to give dark colours known as the browning reaction.

#### **Some properties of celluloses and hemicelluloses :**

They are abundant in the plant kingdom and act primarily as supporting structures in the plant tissues;

They are insoluble in cold and hot water;

#### **Some properties of pectins and carbohydrates gums :**

Pectins are common in fruits and vegetables and are gum like (they are found in and between cell walls) and help hold the plant cells together.

Pectins in colloidal solution contribute to viscosity of the tomato paste;

Pectins in solution form gels when sugar and acid are added; this is the basis of jelly manufacture.

#### **4. Fats**

Generally fruit and vegetables contain very low level of fats below 0.5%. However, significant quantities are found in nuts (55%), apricot kernel (40%), grape seeds (16%), apple seeds (20%) and tomato seeds (18%).

#### **5. Organic acids**

Fruit contains natural acids, such as citric acid in oranges and lemons, malic acid of apples, and tartaric acid of grapes. These acids give the fruits tartness and slow down bacterial spoilage.

Acidity and sugars are two main elements which determine the taste of fruit. The sugar/acid ratio is very often used in order to give a technological characterisation of fruits and of some vegetables.

#### **6. Nitrogen - containing substances**

These substances are found in plants as different combinations : proteins, amino acids, amides, amines, nitrates, etc. Vegetables contain between 1.0 and 5.5 % while in fruit nitrogen containing substances are less than 1 % in most cases.

From a biological point of view vegetal proteins are less valuable than animal ones because in their composition all essential amino-acids are not present.

#### **7. Vitamins**

Vitamins are defined as organic materials which must be supplied to the human body in small amounts apart from the essential amino-acids or fatty acids.

##### ***Vitamin A or Retinol :***

This vitamin is found as such only in animal materials- meat, milk, eggs and the like. Plants contain no vitamin A but contain its precursor, beta-carotene. Man needs either vitamin A or beta-carotene which he can easily convert to vitamin A. Beta-carotene is found in the orange and yellow vegetables as well as the green leafy vegetables, mainly carrots, squash, sweet potatoes, spinach and kale.

##### ***Vitamin C :***

Vitamin C is the anti-scurvy vitamin. Lack of it causes fragile capillary walls, easy bleeding of the gums, loosening of teeth and bone joint diseases. It is necessary for the normal formation of the protein collagen, which is an important constituent of skin and connective tissue. Like vitamin E, vitamin C favours the absorption of iron.

#### **8. Enzymes**

Enzymes are biological catalysts that promote most of the biochemical reaction which occur in vegetable cells.

Enzymes have an optimal temperature - around +50°C where their activity is at maximum. Heating beyond this optimal temperature deactivates the enzyme. Activity of each enzyme is also characterised by an optimal pH.

#### **9. Turgidity and texture**

The range of textures that are encountered in fresh and cooked vegetables and fruit is indeed great, and to

a large extent can be explained in terms of changes in specific cellular components. Since plants tissues generally contain more than two-thirds water, the relationships between these components and water further determine textural differences.

The osmotic pressure within the cell vacuoles and within the protoplasts pushes the protoplasts against the cell walls and causes them to stretch slightly in accordance with their elastic properties. This is the situation in the growing plant and the harvested live fruit and vegetables which is responsible for desired plumpness, succulence, and much of the crispness.

#### **10. Sources of colour and colour changes**

These pigments are classified into four major groups which include the chlorophylls, carotenoids, anthocyanins, and anthoanthins. pigments belonging to the latter two groups also are referred to as flavonoids, and include the tannins.

**The Chlorophylls.** The chlorophylls are contained mainly within the chloroplasts and have a primary role in the photosynthetic production of carbohydrates from carbon dioxide and water. The bright green colour of leaves and other parts of plants is largely due to the oil-soluble chlorophylls, which in nature are bound to protein molecules in highly organised complexes.

In food processing the carotenoids are fairly resistant to heat, changes in pH, and water leaching since they are fat-soluble. However, they are very sensitive to oxidation, which results in both colour loss and destruction of vitamin A activity.

Properties of the anthocyanins include a shifting of colours with pH. Thus many of the anthocyanins which are violet or blue in alkaline media become red upon addition of acid.

#### **Activities of Living Systems**

Fruit and vegetables are in a live state after harvest. Continued respiration gives off carbon dioxide, moisture, and heat which influence storage, packaging, and refrigeration requirements. Continued transpiration adds to moisture evolved and further influences packaging requirements.

It is important to note that the reduction of acid content on ripening influences more than just the tartness of fruit. Since many of the plant pigments are sensitive to acid, fruit colour would be expected to change.

Additionally, the viscosity of pectin gel is affected by acid and sugar contents, both of which change with ripening.

#### **Stability of Nutrients**

One of the principal responsibilities of the food scientist and food technologist is to preserve food nutrients through all phases of food acquisition, processing, storage and preparation. The key is in the specific sensitivities of the various nutrients, the principles of which are illustrated in Table 3.

The ultimate nutritive value of a food results from the sum total of losses incurred throughout its history—from farmer to consumer. Nutrient value begins with genetics of the plant and animal. The farmland fertilisation program affects tissue composition of plants, and animals consuming these plants. The weather and degree of maturity at harvest affect tissue composition.

#### **5. Structural Features**

The structural unit of the edible portion of most fruits and vegetables is the parenchyma cell. While parenchyma cells of different fruit and vegetables differ somewhat in gross size and appearance, all have essentially the same fundamental structure.

The protoplast has inner and outer semi-permeable membrane layers; the cytoplasm and its nucleus are held between them. The cytoplasm contains various inclusions, among them starch granules and plastids such as the chloroplasts and other pigment-containing chromoplasts. The cell wall, cellulose in nature, contributes rigidly to the parenchyma cell and limits outer protoplasmic membrane. It is also the structure against which other parenchyma cells are cemented to form extensive three-dimensional tissue masses.

#### **General Procedures for Fruit and Vegetable Preservation**

Fresh storage

Fresh fruit and vegetable storage :

Once fruit is harvested, any natural resistance to the action of spoiling micro-organism is lost. Changes in enzymatic systems of the fruit also occur on harvest which may also accelerate the activity of spoilage organisms.

**Harvest method** : Considerable research is continuing on mechanical harvesting of perishable crops with a view to minimising damage. In fruit trees, controlling their height by use of dwarfing rootstocks, pruning and growth regulating chemicals will lead to easier, cheaper more accurate harvesting.

**Handling systems** : Field packing of various vegetables for export has been carried out for many years. In the last decade or so this has been applied, in selected cases, to a few tropical fruit types. Where this system can be practised it has considerable economic advantages in saving the cost of building, labour and equipment and can result in lower levels of damage to crops.

**Chemicals** : There is a very strong health lobby whose objective is to reduce the use of chemicals in agriculture and particularly during the post harvest period. Every year sees the prohibition of the use of commonly used post-harvest chemicals. New ways need to be developed to control post-harvest diseases, pest and sprouting.

**Coatings** : Slowing down the metabolism of fruit and vegetables by coating them with a material which affects their gaseous exchange is being tested and used commercially on a number of products.

**Controlled environment transport** : Recent innovations in this technique have produced great progress as a result of the development and miniaturisation of equipment to measure carbon dioxide and oxygen. Several companies now offer containers where the levels of these two gases can be controlled very precisely.

Preservation by reduction of Water Content: Drying / Dehydration and Concentration

Water and water activity ( $a_w$ ) in foods

Micro-organisms in a healthy growing state may contain in excess of 80% water. They get this water from the food in which they grow. If the water is removed from the food it also will transfer out of the bacterial cell and multiplication will stop. Partial drying will be less effective than total drying, though for some micro-organisms partial drying may be quite sufficient to arrest bacterial growth and multiplication.

When we speak of moisture requirements of micro-organisms we really mean water activity in their immediate environment, whether this be in solution in a particle of food or at a surface in contact with the atmosphere.

Two foods with the same water content can have very different  $a_w$  values depending upon the degree to which water is free or otherwise bound to food constituents. Fig. 1 is a representative water absorption isotherm for a given food at a given temperature. It shows the final moisture content the food will have when it reaches moisture equilibrium with atmospheres of different relative humidities.

Preservation by drying / dehydration

The technique of drying is probably the oldest method of food preservation practised by mankind. The removal of moisture prevents the growth and reproduction of micro-organisms causing decay and minimises many of the moisture mediated deterioration reactions.

It brings about substantial reduction in weight and volume minimising packing, storage and transportation cost and enable storability of the product under ambient temperatures, features especially important for developing countries. The sharp rise in energy costs has promoted a dramatic upsurge in interest in drying world-wide over the last decade.

Drying techniques

Several types of dryers and drying methods, each better suited for a particular situation are commercially used to remove moisture from a wide variety of food products including fruit and vegetables.



While sun drying of fruit crops is still practised for certain fruit such as prunes, figs, apricots, grapes and dates, atmospheric dehydration processes are used for apples, prunes, and several vegetables, continuous processes as tunnel, belt trough, fluidised bed and foam-mat drying are mainly used for vegetables. Spray drying is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture/high sugar fruits like peaches, pears and apricots.

As far as dryers are concerned, one useful division of dryer types separates them into air convection dryers, drum or roller dryers, and vacuum dryers. Using this breakdown, table 1 indicates the applicability of the more common dryer types to liquid and solid type foods.

#### Fruit and vegetable natural drying-sun and solar drying

Surplus production and specifically grown crops may be preserved by natural drying for use until the next crop can be grown and harvested. Natural dried products can also be transported cheaply for distribution to areas where there are permanent shortages of fruit and vegetables.

#### Use of preservatives

Preservatives are used to improve the colour and keeping qualities of the final product for some fruits and vegetables. Preservatives include items such as sulphur dioxide, ascorbic acid, citric acid, salt and sugar and can either be simple or compound solutions.

#### Osmotic dehydration

In osmotic dehydration the prepared fresh material is soaked in a heavy (thick liquid sugar solution) and / or a strong salt solution and then the material is sun or solar dried. During osmotic treatment the material loses some of its moisture. The syrup or salt solution has a protective effect on colour, flavour and texture. This protective effect remains throughout the drying process and makes it possible to produce dried products of high quality. This process makes little use of sulphur dioxide.

#### Sun drying

The main problems for sun drying are dust, rain and cloudy weather. Therefore, drying areas should be dust free and whenever there is a threat of a dust storm or rain, the drying trays should be stacked together and placed under cover.

The trays should be placed on a framework at table height from the ground. This allows the air to circulate freely around the drying material and it also keeps the food product well away from dirt. Ideally the area should be exposed to wind and this speeds up drying, but this can only be done if the wind is free of dust. With 80 cm x 50 cm trays, the approximate load for a tray is 3 kg; the material should be spread in even layers. During the first part of the drying period, the material should be stirred and turned over at least once an hour.

#### Shade drying

Shade drying is carried out for products which can lose their colour and/or turn brown if put in direct sunlight. Products which have naturally vivid colours like herbs, green and red sweet peppers, chillies., green beans and okra give a more attractive end product when they are dried in the shade.

#### Identification of Suitable Designs of Solar Dryers for Different Applications

In the selection of appropriate solar dryers for commercial scale operation, it is imperative that economics be kept in view at all time. A total Energy System should be employed and due consideration be given to parasitic energy consumption.

#### Construction of Solar Dryers

In the case of simple natural convection dryers it may be more appropriate to build and operate a number of small units. Multiplicity allows diversity, since more than one crop can be dried at a time. A further advantage is that if one dryer is out of operation due to damage, drying can still continue at reduced capacity using the other dryers.

On the other hand, more sophisticated dryers, such as forced convection solar dryers, benefit from

economies of scale due to the investment tied up in the fan and the source of heat.

### Construction methods and materials

Construction methods and available materials may vary considerable from location to location. It is not within the scope of this document to discuss individual, local circumstances. Some general guidelines regarding factors which must be considered can, however, be given :

I Dimensions of standard materials - Where possible , design should take account of the sizes of material locally available. For example, it would be poor design to specify the width of a corrugated iron collector as 1.1 m if the standard width of a corrugated iron sheet is 1 m.

I Before finalising a design the commercial availability of materials must be ascertained.

I Use of rural materials - The cost of building of solar dryer can be minimised if the producer is able to use wood cut straight from the forest rather than prepared timber. Careful design in the development stage of a dryer can often facilitate the use of cheaper materials. Difficulties caused by these materials are in joining pieces of the structure, in sealing the structure against air leaks, and in attaching the plastic sheet to the (wooden) frame. There is obvious scope for designs which use prepared timber for strategic points and unprepared at others.

### Technical criteria

The following design factors must be established:

I the throughput of the dryer over the productive season;

I the size of batch to be dried;

I the drying period(s) under stated conditions;

I the initial and desired final moisture content of the commodity (if known);

I the drying characteristics of the commodity, such as maximum drying temperature, effect of sunlight upon the product quality, etc.;

I climate conditions during the drying season, i. e. sunlight intensity and duration; air temperature and humidity; wind speed (such data may be available from local meteorological stations);

I availability and reliability of electrical power;

### Socio-economic criteria

From the initial considerations, estimates of the capital costs of the dryer, the price of the commodity to be dried, and the likely selling price of the dried product will have been made. Other question that need to be considered are the following :

I who will own the dryer?

I is the dryer to be constructed by the end-user (with or without advice from extension agencies), local contractors, or other organisations?

I who will operate and maintain it?

I how can the drying operation be incorporated into current practices?

### Sun / Solar drying tray

The drying tray described requires seasoned timber 22.5 mm thick x 50 mm wide.

Cut the timber into lengths of 900 mm long for the sides of the tray and 600 mm long for the ends - 4 pieces of each length will be needed. The ends of each piece are cut as shown in the drawing - this is to make flush fitting joints. Join the corners using small brass screws 20 mm long. To make extra strong joints use good quality wood glue as well as the screws.

The nylon mosquito netting or grass woven mesh can be fitted between the frames as shown in the bottom drawing. Cut the mesh a little larger than the size of the frame. Using drawing pins, pin the mesh to the OUTSIDE edges of one of the frames - the mesh should be pulled tight as the pins are put in around the edges.

### Dryers

Figures 4 to 19 illustrated various types of sun / solar dryers along with examples of drying and dehydration equipment.

### **Preservation by concentration**

Foods are also concentrated because the concentrated forms have become desirable components of diet in their own right. Thus fruit juices plus sugar with concentration becomes jelly. The more common concentrated fruit and vegetable products include items as fruit and vegetable juices and nectars, jams and jellies, tomato paste, many types of fruit purees used by bakers, candy makers and other food manufacturers.

### **Aspects of preservation by concentration**

The level of water in virtually all concentrated foods is in itself more than enough to permit microbial growth. Yet while many concentrated foods such as non-acid fruit and vegetable purees may quickly undergo microbial spoilage unless additionally processed, such items as sugar syrups, jellies and jams are relatively “immune” to spoilage; the difference of course is in what is dissolved in the remaining water and what osmotic concentration is reached.

### **Methods of concentration**

- a) Solar concentration. As in food dehydration, one of the simplest methods of evaporating water is with solar energy. A typical example of this method is production at farm level in developing countries of fruit pastes/leathers (such as apricot or plum pastes).
- b) Open Kettles. Some foods can be satisfactorily concentrated in open kettles that are heated by steam. This is the case for jellies and jams, tomato juices and purees and for certain types of soups. High temperatures and long concentration times should be avoided in order to reduce or eliminate damage. It is also necessary to avoid thickening and burn-on of product to the kettle wall as these gradually lower the efficiency of heat transfer and slow the concentration process.

### **Chemical preservation**

Many chemicals will kill micro-organisms or stop their growth but most of these are not permitted in foods; chemicals that are permitted as food preservatives are listed on other page. Chemical food preservatives are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physico-chemical properties of the foods at or only very little.

Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries, and include sodium chloride (common salt), sugar, acids, alcohols and components of smoke.

### **Lactic acid:**

This acid is the main product of many food fermentations; it is formed by microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavourable for growth of spoilage organisms such as putrefactive anaerobes and butyric-acid-producing bacteria. Yeast and moulds that can grow at such pH levels can be controlled by the inclusion of other preservatives such as sorbate and benzoate.

### **Acetic acid:**

Acetic acid is general preservative inhibiting many species of bacteria, yeasts and to a lesser extent moulds. It is also a product of the lactic acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) includes products such as pickles, sauces, and ketchup.

### **Commonly used lipophilic acid food preservatives**

Benzoic acid in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and

jellies, sauerkraut, pickles, preserves, fruit cocktails, etc. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.

Sorbates are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, sauerkraut, syrups, jellies, jams, preserves, high moisture dehydrated fruits, etc.

### **Gaseous chemical food preservatives**

Sulphur dioxide and sulphites. Sulphur dioxide (SO<sub>2</sub>) has been used for many centuries as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml. at 25°C).

Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and metabisulphite salts which are powders. The gaseous form is produced either by burning sulphur or by its release from the compressed liquified form.

Metabisulphite are more stable to oxidation than bisulphites, which in turn show greater stability than sulphites.

### **chlorine**

The various forms of chlorine constitute the most widely used chemical sanitiser in the food industry. These chlorine forms include (Cl<sub>2</sub>), sodium hypochlorite (NaOCl), calcium hypochlorite (Ca(OCl)<sub>2</sub>) and chlorine dioxide gas (ClO<sub>2</sub>).

These compounds are used as water adjuncts in processes such as product washing, transport, and cooling of heat-sterilised cans; in sanitising solutions for equipment surfaces, etc.

### **Food Irradiation**

Food irradiation is one of the food processing technologies available to the food industry to control organisms that cause food borne diseases and to reduce food losses due to spoilage and deterioration.

Food irradiation technology offers some advantages over conventional processes. Each application should be evaluated on its own merit as to whether irradiation provides a technical and economical solution that is better than traditional processing methods.

### **Applications :**

For products where irradiation is permitted, commercial applications depend on a number of factors including the demand for the benefits provided, competitiveness with alternative processes and the willingness of consumers to buy irradiated food products. There are a number of applications of food irradiation. For each application it is important to determine the optimum dosage range required to achieve the desired effect. Too high a dosage can produce undesirable changes in texture, colour and taste of foods.

### **Chemical Preservation of Foods**

The essential value of selected chemical compounds in preserving foods, the benefits derived by their judicious applications, and the general principles governing their uses have received attention in most governments and their laboratories. The matter is so important that it was and is the subject of many national and international conferences.

In the United States the National Academy of Sciences (NAS) - National Research Council (NRC), the President's Science Advisory Committee Panel on Chemicals and Health, and expert committees from governmental agencies, universities and industries have focused on the area. The Food and Agriculture Organisation (FAO) and the World Health Organization (WHO) of the United Nations have also been active in this field, approaching the matter from an international point of view, generally embracing the important features of the thinking of most nations in the world.

As a result, a growing body of knowledge has become available which has coalesced and yielded insights into this important subject.

## **WHAT ARE FOOD ADDITIVES?**

In the United States the Food Protection Committee of the NAS/NRC defined a food additive a substance or a mixture of substances, other than a basic foodstuff, which is present in food as a result of any aspect of production, processing, storage or packaging. The term does not include chance contamination.

It is clear that there are intentional additives which are added to perform specific functions. There are incidental additives which really have no function in a food product but become part of a food product through some phase of production, processing, storage or packaging. Food additives do not include those substance which may find their way into food accidentally, inadvertently or unintentionally. The terms do not include pesticides, for example, nor color additives, new animal drugs or any substance used in accordance with a sanction or approval granted prior to the effective date of the Food Additives Amendment of 1958.

### **Legitimate Uses in Food Processing**

Food additives have a legitimate use in the food processing and distribution systems of both technologically advanced and of less well developed countries, in promoting the utilization of available foods.

The use of food additives to the advantage of the consumer may be technologically justified when it serves the following purposes :

- (1) The maintenance of the nutritional quality of a food.
- (2) The enhancement of keeping quality or stability with resulting reduction in food losses.
- (3) Making foods attractive to the consumer in a manner which does not lead to deception.
- (4) Providing essential aids in food processing.

### **CHEMICAL PRESERVATIVES**

The Federal Food, Drug and cosmetic Act designates any chemical which when added to a food tends to prevent or retard its deterioration as a chemical preservative.

Every chemical added to a food during the process of its fabrication is not necessarily considered to be a preservative. For example, in canning, if the air in the headspace is displaced with nitrogen, the gas is not considered a chemical preservative added to the food.

In the United States chemical preservatives added to foods must be stated on the label, stating the chemical as an ingredient. The name of the chemical must be declared in terms understandable to consumers. If two or more chemical preservatives are added to a food, each must be stated individually.

### **Microbial Antagonists**

There are two large categories of microbial antagonists useful in food preservation; those of inorganic nature and those of organic nature. Examples of each will be discussed.

**Inorganic Agents.** - *Sulfur Dioxide.* - Sulfur containing compounds are extremely useful to mankind. Sulfur dioxide has been used in food preservation for centuries. It currently still finds widespread use throughout the world, principally in treating foods of plant origin. Being more effective against molds than yeasts, Sulfur dioxide has found wide use in the fermentation industries, such as wine making. Sulfur dioxide is much more toxic to molds and bacterial than in yeasts.

Sulfur dioxide is used in concentrations upwards to 2000 ppm in the preservation of fruit concentrates. Sulfur dioxide is thought to be an enzyme poison, and finds use in controlling enzymatic browning during drying of foods. The burning of sulfur, and the occurrence of sulfur houses of one form or another in drying yards, has been observed in most countries.

A proposed process for sterilizing fluid whole milk involves the addition of 0.1% hydrogen peroxide to fluid milk allowing a reaction time of several minutes for sterilization, adding sterilized catalase to decompose residual hydrogen peroxide, then heating to inactivate the enzyme. Combined with aseptic packaging, the process theoretically has potential. One objection is the damaging influence of the liberated oxygen.

Anaerobic spore forming bacteria can be killed with hydrogen peroxide. Surface sterilization of many commodities may be accomplished. In this regard, hydrogen peroxide finds wide usage in controlling surface infections of man.

Hydrogen peroxide is not a permitted additive to foods in the United States.

*Chlorine* - Chlorine is a widely used chemical disinfectant, finding as important use in the treatment of water for drinking and processing purposes. Its action is most effective at low pH values.

### **Antibiotics**

Living tissues produce metabolic products. Some of these products from microorganisms have been found to have germicidal properties, and are called antibiotics. Living tissues contain other materials which have antimicrobial activity, but the term antibiotic is restricted to those materials yielded in metabolism by microorganisms. Spices may contain antimicrobial compounds, yet the active ingredients are not called antibiotics.

### **Food Preservation by Canning**

Nicolas Appert, a French confectioner working in a simple kitchen, observed that food heated in sealed containers was preserved if the container was not reopened or the seal did not leak. He modestly called the process "the art of Appertizing". Appert received the award from Napoleon after spending ten years proving his discovery.

It should be appreciated that the cause of spoilage of food was unknown. The great scientists of the day were summoned to evaluate Appert's process and offer explanations for its apparent success. The conclusion reached was that the process was successful because in some mysterious and magical fashion air combined with food in a sealed container, preventing putrefaction. This was quite incorrect. Nevertheless, the canning process was discovered and practiced for the next 50 years with some success, but in the darkness of ignorance.

### **SPOILAGE OF FOOD CAUSED BY MICROORGANISMS**

To the Academy of Sciences in France in 1864, Pasteur reported that he had found the cause of the disease of wine and beer to be a microscopic vegetation. When given favorable conditions this vegetation grew and spoiled the products. However, boiled wine sealed from contamination in jars with even cotton plugs would not sour. In fact, it was possible to isolate this microscopic vegetation from the cotton plugs! It was this microscopic growth which spoiled foods, and it was necessary for such organisms to gain entrance to heated foods if they were to spoil! Here was an explanation for the success of Appert more than half a century before. The concept of heat treating foods to inactivate pathogenic organisms is termed appropriately "pasteurization" today.

Appert had established that containers of food must be carefully sealed and heated. Cleanliness was important to his process, although he did not know that microorganisms were the agents of spoilage. Pasteur established several important principles. Most changes in wine depended on the development in it of microorganisms which were themselves the spirits of disease. Germs were brought by air, ingredients, machinery and even by people. Whenever wine contained no living organisms, the material remained undiseased. Some of Pasteur's flasks remain, and are presumably still sterile today.

### **Heat Resistance of Microorganisms Important in Canning**

There are two important genera of bacteria which form spores. Both genera are rod forms, one (*Bacillus*) is aerobic and the other (*Clostridium*) is anaerobic. When a rod is about to sporulate a tiny refractile granule appears in the cell. The granule enlarges, becomes glassy and transparent, and resists the penetration of various chemical substances. All of the protoplasm of the rod seems to condense into the granule, or young spore, in a hard dehydrated, resistant state. The empty cell membrane of the bacterium may separate off, like the hull of a seed, leaving the spore as a free, round or oval body. Actually a spore is an end product of a series of enzymatic processes. There is no unanimity of opinion either of spore function in nature or of the

factors concerned in spore formation.

Spores appear to be formed by healthy cells facing starvation. Certain chemical agents (glutamic acid) may inhibit the development of spores. No doubt sporulation consists of a sequence of integrated biochemical reactions. The sequence can be interrupted at certain susceptible stages.

Heat may be applied in two ways for the destruction of bacteria. Oven heat may be considered as dry heat, used in the sterilization of glassware. Other materials are heated when moist or in the presence of moisture; this is commonly termed moist heat. Dry cells exhibit no life functions; their enzyme systems are not active. Cell protein does not coagulate in the absence of moisture.

### **CATEGORIES OF FOODS FOR CANNING**

It is possible to classify foods to be canned on the basis of acidity and pH value. Plant tissue (except fruits and berries) and animal tissue (including meat, fish and dairy products) are classed as low acid foods. Manufactured items with several ingredients may fall into the medium acid group. Fruits are in the acid group. Berries, fermented products and certain citrus products fall into the high acid group as do jams and jellies. Few foods are basic in reaction if considered in their best quality.

### **Influence of Food Ingredients on Heat Resistance of Spores**

**Acids and pH Value of Heating Medium.**-Of the many factors which influence the heat resistance of spores, the pH values of the heating medium has profound effects. For most spore-forming bacteria maximum resistance generally occurs in the region of neutrality. Bacterial spores are not heat resistant at low pH values. For foods with pH values higher than 5.0 apparently factors other than pH are important in the resistance of spores. For instance, the heat resistance of spores of *Cl. botulinum* in fish products with a range in pH from 5.2 to 6.8 is approximately the same. at a pH lower than 5.0, a marked reduction in resistance occurs. This effect is utilized in the processing of certain vegetables and other low acid foods which do not withstand sterilization under usual canning conditions. The liquors in which these foods are packed are acidified, with the result that the resistance of the contaminating organisms is lowered.

Altering the pH of tomato juice with citric, lactic or acetic acid greatly alters the heat resistance of *B. thermoacidurans*. If the same percentage of acid is added, they differ in their degree of effectiveness in lowering the heat tolerance of the organisms in the order of lactic, citric and acetic. If based on the pH, the order would be acetic, lactic and citric. Evidently the undisassociated acid molecule is important in this phenomena.

**Reactivation of Enzymes After Heating** - Although substantial attention has been given to the destruction of enzymes in other methods of food preservation (freezing, dehydration) relatively little has been given in canning foods. The assumption has been that the heat process designed to kill microorganisms is sufficient to inactivate all enzymes. While it is true that heating to 79 C will inactivate many enzymes, it is only recently that studies have been undertaken to evaluate the heat resistance of enzymes in canned foods. Enzymes play a role in the deterioration of canned acid and high acid foods. Also, enzymes are in some instances reactivated after heating (i.e. peroxidase). This problem has developed from studies of extremely high temperature processing (121° to 149°C flash-heat treatments). Microorganisms are heat inactivated but indications are that some enzymes do survive such treatments. The peroxidase in pickles is able to withstand heating to 85°C. The heat destruction of this enzyme is increased by the addition of vinegar. Heavy sugar solutions are protective to enzymes to heat inactivation in pears and peaches. The enzymes of the tomato are not altered in heat resistance by the small amount of salt added. Some suggestions that the enzymes of canned tomatoes remain active after the canning process are available. Peroxidase systems of turnip and cabbage have been found to be reactivated after heating.

Thermal destruction curves obtained for ascorbic acid oxidase and peroxidase in acid foods indicate that standard methods may be used in evaluating the heat inactivation of enzymes.'

The internal temperature of fruit and vegetables in the high acid food group, which receive relatively low heat processes in canning, may not rise sufficiently high to inactivate enzymes normally present internally in these tissues. The pectinesterase in canned grapefruit juice is active after an adequate process from the standpoint of microbial spoilage has been administered.

**Enzymes-A Chemical Index of Efficiency**-In some instances the inactivation of enzymes may be used as an index of the degree of heating of foods. For instance, the pasteurization of milk can be evaluated by its phosphatase enzyme activity. The destruction of phosphatase in milk coincides with the heat treatment designed to kill *B. tuberculosis* and other human pathogenic organisms. An evaluation of milk for this enzyme indicates the minimum degree of heat treatment.

The peroxidase system in fruits may be useful in evaluating the relative efficiency of acid food canning processes. Unless the enzymes are destroyed, they will continue to function in the container, causing deterioration. So too, if the presence of one enzyme is found, what conclusions are possible relative to the hundreds of others which may be functional, but for which there are no methods of evaluation?

**Heat Penetration Characteristics of Canned Foods** - When a can of food is sealed at 98°C and placed in a steam pressure vessel which is brought to 121°C, the steam chamber is the reservoir of high heat energy and the can of food is the reservoir of lower heat energy. Heat then is transferred from the hot body to the cold. The mechanism of heat transfer in canned food during such thermal processing may be divided into several rather definite classes. To a certain extent it is possible to place food into heat transfer classes by knowing their physical characteristics. The heat is transferred by conduction from the steam to the can, and from the can to the contents.

**Measuring the Heat Penetration into Canned Foods**- While thermometers can be used to follow certain heating characteristics of foods, the most satisfactory method involves the use of thermocouples. A thermocouple is formed when two dissimilar metal wires are fused together at the ends. If the ends of these wires are placed at different temperatures a measurable voltage is developed, which is related to the temperature difference between the two ends or thermocouple junctions. By attaching a suitable measuring device (potentiometer) to the thermocouple, it is possible to calibrate it and follow the temperature changes inside a can which itself is being heated in a retort under steam pressure. A commonly used thermocouple system is composed of copper-constantan wires and a potentiometer, reading directly in degrees centigrade. Recording potentiometers are also available.

### **GENERAL METHOD FOR CALCULATING THE PROCESS TIME FOR CANNED FOODS**

With information relative the heat resistance of spoilage organisms to be destroyed in canning and the heating characteristics for the food in question, the information necessary to calculate the processing time for the product is available. Each time-temperature interval during the heating and cooling of the containers has a lethal effect on food spoilage organisms, if the temperatures are above the maximum for growth for the organisms. By correlating the killing effects of these high temperatures with the heating rate of the food, the length of time theoretically required to destroy any specific bacterial spores present in the container of food may be calculated for any given temperature.

### **INOCULATED PACK STUDIES**

In order to ensure that the calculated processing time for a product is adequately established, it is desirable to prepare inoculated packs. The product is prepared and filled into containers. An inoculum of spores of the spoilage organism, important in the food group in which the product falls, is placed at approximately the cold point in the containers. With viscous foods, such as strained pumpkin, the inoculum will remain somewhat at the position placed. For convection heating foods, the inoculum will be carried in the convection currents formed during heating the containers. For solid packed foods such as potatoes, the inoculum should be injected with needle  $\frac{1}{4}$  in. into the flesh of a potato at the cold point. Excessive



processing would be required to kill spores in the center of a 2-in, diameter potato. The inner surfaces are assumed to be sterile.

### **Adequacy of Heat Processes**

There are two considerations relative to safe processing schedules developed: one relative to the heat resistance of spoilage microorganisms, and the other relative to the heat penetration characteristics of the food in the containers.

Statistical Evaluation of Heat Processes.- When process time is plotted against its lethal value, the relationship between the two variables, if considering a range of processes, is generally linear. In view of this, a linear regression line may be fitted to the lethal value-process time data for each product and the standard error of estimate computed.

The process times determined for products by the three methods (i.e., slowest heating-fastest cooling composite data from heat penetration studies, inoculated pack studies, and the statistical evaluation) contain certain margins of safety. Under certain sanitary conditions they may be excessive. Under poor processing conditions they may be inadequate!

### **SPOILAGE OF CANNED FOODS**

The ends of normal cans of food with a vacuum are slightly concave. Ends which are bulged may be caused by microbial, chemical or physical actions. A hard swell is one which resists being pushed back to a normal position. The ends of a soft-swelled can may be forced back slightly but will not resume a normal condition. A springer swell is one which is bulged but which may be forced back into normal position causing the opposite end to bulge by hitting against a solid object. The opposite end flips into the bulged end. Cans may progress through the flipper, springer, soft swell and hard swell stages. The next step is to have the can explode.

When anaerobic spore-forming organisms are causes of spoilage, it is usual that the contamination comes from the raw material. It is unlikely that conditions in a plant are favorable for inoculation of anaerobes into products.

Solid products such as meat which have spoiled may have center portions still sterile. The growth may be centered outside the product or on the surface. Internal tissues of plants and animals normally do not contain organisms if the tissues are not diseased.

### **Microbial Spoilage**

Flat Sour.-Spoilage of canned foods needs not be accompanied by bulged ends. Flat sour spoilage, as the term implies, is a condition of high acid formation unaccompanied by gas production. Thermophilic bacteria are characteristic in the production of such spoilage. In flat sour spoilage, either the cans have been under-sterilized or the cans have leaked.

Lacquered cans may be more easily perforated than plain cans, due to the fact that areas of exposed iron are not afforded cathodic protection or the protection of dissolved tin. Imperfections in the lacquered surface tend to concentrate this chemical activity to small areas, and perforation may be rapidly accomplished.

Lids on glass container may be attacked chemically by some foods.

Physically Induced Swells - Overfilling cans at low temperatures may cause permanent bulging to cans by heating. Expansion of the solids and liquid of the container may permanently distort it.

Foods packed with low vacuums may bulge when placed at high altitudes where there is lower atmospheric pressure.

### **STORAGE OF CANNED FOODS**

If the canning processes have been successful, the containers should be in a condition where biological spoilage will not occur. Thermophilic organisms may be present, but unless temperature conditions in the storage chamber are excessive such spoilage is unlikely. However, while the biological forces may not be operative, chemical reactions are not eliminated. Chemical reactions bring about many changes in canned

foods during storage.

### **External Corrosion of Cans**

The presence of moisture on the surfaces of cans leads to rust formation. Rusting conditions may result from “sweating” of containers when moisture from air condenses on cans when their temperature is below the dew point of the air. When the relative humidity is high and the temperature of the cans is low, condensation may be expected. Warehousing at dry atmospheric conditions and constant low temperatures is important to prevent deterioration of cans and products. Proper air circulation, heating or cooling, and ventilation around stacks of cased products with adequate temperature control, reduce danger to corrosion of cans.

### **Food Preservation by Fermentation**

#### **LIFE WITH MICROORGANISMS**

Microorganisms no doubt outnumber other living entities on this planet and can be found existing actively or passively wherever living organisms occur. While the energy for life on this planet is captured by green plants in the photosynthetic process, microorganisms are generally responsible for the final decomposition of the photosynthetic products. Animals play a minor role in the cycle.

While microorganisms were not identified as the important agents in food spoilage until a century ago, wine making, bread baking, cheese making and salting of foods have been practised for more than four thousand years. For all those years mankind practiced food preservation using unknown, invisible, active, living organisms.

#### **FERMENTATION OF CARBOHYDRATES**

The word fermentation has undergone evolution itself. The term was employed to describe the bubbling or boiling condition seen in the production of wine, prior to the time that yeasts were discovered. However, after Pasteur’s discovery, the word became used with microbial activity, and later with enzyme activity. Currently the term is used even to describe the evolution of carbon dioxide gas during the action of living cells. Neither gas evolution nor the presence of living cells is essential to fermentative action, however, as seen in lactic acid fermentations where no gas is liberated, and in fermentations accomplished solely with enzymes.

### **Industrially Important Organisms in Food Preservation**

The application of microorganisms to food preservation practices must be such that a positive protection is available to control contamination.

The microorganisms used in fermentations are notable in that they produce large amounts of enzymes. Bacteria, yeasts and molds, being single cells, contain the functional capacities for growth, reproduction, digestion, assimilation and repairs in a cell, that higher forms of life have distributed to tissues. Therefore, it is to be anticipated that single celled complete living entities (such as yeasts) have a higher enzyme productivity and fermentative capacity than found with other living creatures.

### **Fermentation Controls**

Foods are contaminated naturally with microorganisms and will spoil if untended. The type of action which will develop is dependent upon the conditions which are imposed. The most favorable to a given type of fermentation under one condition will be altered by slight changes in a controlling factor. Untended meat will naturally mold and putrefy. If brine or salt is added, entirely different organisms will take over.

Source of Energy - Inasmuch as the immediate need of microorganisms is a source of energy, the soluble, readily available carbohydrates influence the microbial population that will dominate. In milk the sugar is lactose; those organisms which quickly mount in numbers are the lactose fermenting organisms. Because suitable energy sources are generally available to microorganisms in man’s foods, energy sources are not usually a limiting factor, with certain exceptions (such as milk).

Milk held at 0°C has little microbial activity, and retarded expansions in bacterial numbers. At 4°C there is slight growth of organisms and more rapid development of off-flavors.

The temperature at which a food is held will determine within certain limits the nature of the organisms capable of either yielding the desired fermentation or spoilage, whichever the case may be.

## **WINE**

Wine and beer or similar fermented products originated in antiquity. Alcoholic beverages were discovered by man in many areas on earth, with the exception of the early American Indian. There was a fermented cactus juice known to certain tribes in the Southwest, but evidently alcohol was not a commodity in America as it was in the ancient Egyptian, Greek, Roman, and oriental civilizations. The ability to produce pleasant, palatable effervescent beverages by fermentation of natural fruit juices is a demonstration of man's inherent ingenuity. From earliest recorded history wine and beer have been important items of trade.

Aging of wines improves the flavor and bouquet due to oxidation and formation of esters. These esters of higher acids formed during aging give the ultimate pleasing bouquet to well aged wine. Aged wine may be polished by filtration to give a clear, bright appearance prior to bottling.

### **Preservation**

Pasteurization is applied in one of three ways : (1) by flash pasteurizing and returning to the storage tank; (2) flash pasteurizing into the final bottle; and (3) pasteurization by heating the filled and sealed bottle. There is also some bulk pasteurization and hot holding at a temperature of 49°C for several days to stabilize wines, usually dessert types.

In flash pasteurizing in bulk, wine is heated for about 1 min to 85°C and is then cooled continuously against the incoming wine and water or refrigerant cooled pipes.

The time-temperature relationship for pasteurization of wines is: vegetative yeast cells are killed at 40°C while yeast spores are only killed at 57°C.

### **Sterilization Filtration**

Wine and fruit juices can be rendered sterile, germ or yeast free, by filtration through sterile, very tight filter pads. The Seitz process of sterile filtration includes three stages : sterilizing, filling and corking. Sterilizing of bottles is accomplished by use of sulfur dioxide gas, by removal of the gas with sterile water, filling under pressure, and corking with sterile corks. When sulfurous acid solutions are employed to sterilize the bottles, the bottles must be well drained in order to prevent excessive pickup of sulfur dioxide. The filter plates, pipes, hose lines, etc., beyond the filter to the bottling machine, and the latter, and the bottles and corks, must be sterilized and kept sterile during filtration and bottling.

Wine making remains an art and a science, dependent on nature to yield environmental conditions for grape culturing. Certain localized areas have the proper combination of soil type, sunlight, temperature, and rainfall required for grape growing. These regions have become known throughout the world. Examples are found in the Rhine and Rhone valleys of Europe, and in areas of New York and California. Expert wine tasters are able to locate generally the vineyard area from which the grapes for a wine have come.

## **BEER**

Beer and ale are fermentation products with characteristic flavor and aroma from malt and hops. The alcoholic content ranges from 3 to 7%. The strain of yeast used, the composition of the wort, and the temperature of fermentation are controlling factors. Hops has at least two antibacterial components in addition to having a role in flavoring. Boiled wort must be inoculated with yeast at the start of the fermentation. Packaged beer is usually pasteurized while barrelled beer is not. Pasteurization temperatures of 64°C are commonly used.

### **Cold Pasteurization**

For many years attempts were made to capture the unheated flavor of casked draft beer in bottles and

cans for home use. Recently success was achieved by using a cold pasteurization technique. This employs newly developed microporous membrane filters which physically remove the majority of bacteria and larger yeasts. Using filtration of this kind rather than heat, microbial numbers are effectively decreased and the flavor of draft beer is largely preserved.

### **VINEGAR FERMENTATION**

Vinegar is a condiment prepared from various sugary or starchy materials by alcoholic and subsequent acetic fermentation. It consists principally of a dilute solution of acetic acid in water, but also contains flavoring, coloring and extracted substances, fruit acids, esters, and inorganic salts, varying according to its origin. Although acetic acid is the active ingredient of all vinegars, these additional substances give distinctive and pleasing quality to the product. Vinegar may be produced from the juices of most fruits such as apples, grapes, cherries and pears, but cider vinegar has always been the most popular in the American home. The principles involved and method of preparing cider vinegar will be discussed herein.

Cider vinegar which during the course of manufacture has developed in excess of 4% of acetic acid, may be reduced to a strength of not less than 4%. Cider vinegar so reduced is not regarded as adulterated, but must be labeled to this effect as diluted cider vinegar.

#### **Principles of Vinegar Fermentation**

The manufacture of vinegar requires two fermentation processes. The first transforms the sugar into alcohol, by yeast. The second changes the alcohol into acetic acid and is brought about by vinegar bacteria. One of the chief causes of failure in preparing vinegar, and a factor not often considered, is that vinegar-making involves two very distinct and different fermentations. The first must be completed before the second begins.

### **VINEGAR MAKING**

The juice of ripe apples has been found to vary in the sugar content between 7 to 15% with an average for a large number of varieties in several states being near 11%. Generally, the juice from summer apples has the lowest sugar content, winter apple juice the highest, and fall apple juice somewhere between the two. Mature apples in the ripe stage contain the largest amount of sugar, green apples a much smaller amount, and over-ripe fruit less than ripe fruit. The juice should be expressed and collected.

#### **Food Preservation by Drying**

##### **DRYING-A NATURAL PROCESS**

Drying is one of man's oldest methods of food preservation. It is a process copied from nature; we have improved certain features of the operation. Drying is the most widely used method of food preservation.

All the cereal grains are preserved by drying, and the natural process is so efficient it hardly requires added effort by man. However, there have been periods in history when climatic factors were such that grains failed to dry properly in the fields. In these instances, man attempted to assist the natural action by supplying heat to the grains which otherwise would decompose. Grains, legumes, nuts and certain fruits nature on the plants and dry in the warm wind. More fruits are preserved by drying than by any other method of food preservation. The natural sun drying of foods yields highly concentrated materials of enduring quality, yet a highly complex civilization cannot be so dependent upon the elements-they are unpredictable. Sun drying remains the greatest food preservation action.

##### **ADIABATIC DRIERS**

Cabinet Driers -The drier consists of a chamber in which trays of product can be placed. In large driers the trays are placed on a truck for ease of handling. In small units trays may be placed on permanent supports in the drier. Air is blown by a fan past a heater (usually finned steam coils) and then across the trays of material being dried.

The cabinet drier is usually the least expensive drier to build, is easy to maintain, and is quite flexible. It is commonly used for laboratory studies in the dehydration of vegetables and fruits, and in small scale and

seasonal commercial operations.

### **HEAT TRANSFER THROUGH A SOLID SURFACE**

**Drum Driers.**-Steam heated rotating drums 1 to 2 m in diameter are used for dehydration of fluid products. The slurry is deposited on the drum in a thin film. Heat is transferred through the drum wall to the product film. The drum may be exposed to the atmosphere or it may be held under a vacuum. The dried product is removed from the drum by a scraper blade. The dried film then may be ground to a fine powder.

**Vacuum Shelf Driers** -These consist of a cabinet with hollow shelves. The product is placed in pans on the shelves or, if solid, it can be laid directly on the shelves. The unit is closed and a vacuum drawn, Steam, hot water, hot oil, Dowtherm or some other suitable heating medium is circulated through the hollow shelves, heating the product. These units are expensive and have been used mainly on such products as “puff-dried” citrus powder, tomato powder and other food products.

**Continuous Vacuum Driers** -These driers consist of a stainless steel belt on which the product is deposited. The film on the belt passes over a heating source, a heating drum or a grid of steam coils, and heat passes through the belt to the product film. In some cases, additional heat may be supplied from the top by infrared lamps. The entire unit is enclosed and held under a vacuum.

### **FREEZE-DEHYDRATION (FREEZE DRYING)**

By using high vacuum condition it is possible to establish specific conditions of temperature and pressure whereby the physical state of a food substrate can be maintained at a critical point for successful dehydration, with greatly improved rehydration potentialities. Such is a system developed in recent years which has been called freeze-dehydration.

### **INFLUENCE OF DRYING ON MICROORGANISMS**

Pathogenic bacteria are occasionally able to withstand the unfavorable environment for them in dried foods, then create a public health hazard when eaten. Notable are infections by enteric organisms and food poisoning organisms in general. It is a common technique to dry cultures (by lyophilization techniques) for storage. Under these conditions there is a slow, steady decrease in the number of surviving populations. Similar experiences are found with bacterial contaminants of dried food.

### **INFLUENCE OF DRYING ON ENZYME ACTIVITY**

Enzymes are sensitive generally to moist heat conditions, especially where temperature range above the maximum for enzyme activity. Moist heat temperature near the boiling point of water finds enzymes nearly instantaneously inactivated. There are exceptions, but as a rule a minute at 100°C renders enzymes inactive.

When exposed to dry heat at the same temperature, such as used in drying, enzymes are notably insensitive to the effect of the energy. Short exposure to temperatures near 204°C have little effect on enzymes if the heating medium and the enzyme preparation is dry.

### **DEHYDRATION OF FRUITS**

A great volume of fruit is sold as dry fruit with a moisture content of 15 to 25%. This can be achieved by placing fruit in trays for either sun drying, kiln drying or tunnel drying. Some fruit juice powders have been produced by adding a corn syrup to the juice and vacuum or spray drying.

### **DEHYDRATION OF VEGETABLES**

In dehydration of vegetables, enzyme systems must be inactivated. This is accomplished usually by heating in boiling water or steam. Many vegetables are more stable if given a treatment with sulfur dioxide or a sulfite. The moisture content of vegetables should be less than 4% if satisfactory storage life and quality retention are to occur. Residual moisture contents can be reduced to these levels in practice by in-package desiccants.

Vegetables are usually dried in tunnel, cabinet or belt driers. For some powdered vegetable products, drum

driers and spray driers have been used. The amount of dried vegetables on the market is relatively small and limited in variety. Potatoes are the largest single item. Most of the other products are items such as onion, celery, parsley, and their powders which can be used as flavoring ingredients. Some dehydrated vegetables are sold in soup mixes and some are used in manufacturing canned products. Much developmental work needs to be done.

### **DEHYDRATION OF ANIMAL PRODUCTS**

Meat is usually cooked before it is dehydrated. The moisture content of the meat at the time of entry into a drier is about 50% and when dried should be approximately 4% for beef or pork. Mildly cured vacuum packed bacon spoils because of the growth of many species of microorganisms. Mildly cured, vacuum packed, sliced bacon has a shelf-life of at least six months if it is sufficiently dehydrated before canning to have moisture content to salt ratio of 5:1

#### **Dehydration of Fish**

#### **Dehydration of Milk**

#### **Dehydration of Eggs**

### **PACKAGING OF DEHYDRATED FOODS**

Eggs, meat, milk and vegetables are ordinarily packaged in tin containers. Occasionally fiberboard or flexible film material may be employed, although they are not as satisfactory as tin. Tin offers protection against insects, moisture loss or gain, and permits packaging with an inert gas. If packaged dehydrated foods are to be stored for a considerable period of time, it is advisable to use low temperature storage.

For long-term storage, of dehydrated foods, functional containers which are hermetically sealed and resistant to penetration by insects are required.

The packaging requirements of dried foods are product specific.

#### **Canning Fruits**

##### **Apple**

Apples are not canned to any great extent, since they can be kept in refrigerated or controlled atmosphere storage for practically the whole year from one season to another. Canned apples, which are usually available in the larger sizes of cans, are generally used in pies. The varieties commonly employed for canning are : Yellow Newton, Pippin, Spitzenberg, Winesap, Baldwin, Russet, Jonathan, Delicious, and Rome Beauty.

##### **Apricot**

Apricots are canned largely in the U.S.A. In India, these grow mostly in Kashmir, Simla Hills and Uttar Pradesh, where considerable scope exists for their canning.

Apricots are not peeled for canning. They are merely cut into halves and the stones removed. Sometimes, they are canned whole. According to Cruess, on an average, a ton of apricots yields about 55 cases of 24 A 2 ½ size cans. Siddappa has reported an average yield of 58 cases per ton of apricots.

##### **Banana**

Banana is one of the most important fruit crops of India. More than 200 commercial varieties are grown over an area of about 1,60,000 hectares.

Fully ripe fruit is peeled by hand and cut laterally into slices of 1.27 cm to 1.89 cm thickness. Sugar syrup of 25 to 30° Brix, containing 0.2 per cent citric acid is used as covering liquid. The pH of the banana has been found to vary from 4.5 to 5.3. Butter size cans (1 lb squat) are processed for 15 minutes in (i) boiling water (100°C), if the pH of the fresh fruit is 4.8 or less, and (ii) in a pressure cooker at 5 lb psi (0.35 kg per cm<sup>2</sup>) steam pressure (sea level), if the pH is higher than 4.8. Cooling after processing should be quick and thorough to prevent pink discolouration of the slices in the can during storage.

##### **Black berries**

Black berries are canned to some extent in the U.S.A. and in the U.K. They are not available in any large

quantity in India for commercial canning. Evergreen Mammoth and Himalaya are the more important canning varieties. The berries should be handled without any delay after harvesting.

### **Cherries**

The cherries are packed in barrels of brine containing calcium hydroxide, sulphur dioxide, and occasionally alum. According to Cruess in California, the brine for this purpose is made up of about 0.75 to 1.0 per cent SO<sub>2</sub> and about 0.4 to 0.6 per cent of slaked lime in Oregon, approximately 1.5 per cent of SO<sub>2</sub> and about 0.9 per cent of lime are used. The brined cherries are stored for 4 to 6 weeks for curing. During this period, the colour of the cherries changes to white or pale-yellow. The cured cherries are washed well in water and dyed with a red dye such as erythrosin, and the colour fixed with citric acid. These coloured cherries are used for canning or for candying.

### **Grape**

Muscat and Thompson Seedless are good canning varieties. Only large sized berries are used for canning. Syrup of 20° to 40° Brix is used. Loss in canning is nearly 20%. According to Siddappa and Ishaq, the Seedless Kishmish and the Seeded Haitha grapes give good canned products. Coloured grapes should be canned in lacquered cans.

### **Jack-fruit**

Jack-fruit (*Artocarpus integrifolia*) is available in plenty in Maharashtra, Bihar, Orissa, Karnataka, Kerala and some parts of Tamil Nadu. It is an important staple food for certain sections of the people in these areas. The tree bears annually 60 to 75 fruits, each weighing 10 to 20 kg. In exceptional cases, the fruit weighs even 35 to 40 kg. The unripe green and immature fruit is prized as a vegetable. Experiments have shown that green jack-fruit can be canned as a curried vegetable. The crisp bulbs (seeds removed) of the ripe fruit are used for canning in syrup. The yield of bulbs varies from 25 to 40 per cent of the weight of the fruit.

### **Litchi**

Litchies are found in Uttar Pradesh, Bihar and Orissa. For canning, the fruit should be tree-ripened. The outer shell is first cracked, then the pulp inside is separated, and finally the stones are removed. Plain can and 40° Brix syrup with 0.5 per cent citric acid are used. Prompt and thorough cooling of the cans after processing is necessary to prevent development of pink colour in the product. Canned litchies from China are well known in foreign countries.

### **Loquat**

Loquats can be cut into halves and canned to get an attractive product.

### **Papaya**

Papaya slices or cubes, can be used for canning. About 0.5% citric acid should be added to the syrup to counteract the high pH of the fruit. Papaya could be canned along with other fruits like pineapple, mango, banana, etc. to get a product similar to the one commercially packed in Australia. Papaya being a quick growing fruit, can form the basis for a thriving canning industry. It also yields valuable by-products such as the enzyme papain and jelly-forming pectin. An integrated approach to the utilization of this fruit has been investigated by Siddappa and his co-workers at the Central Food Technological Research Institute, Mysore.

### **Syrups and Brines for Canning**

For canning fruits and vegetables, different covering liquids are employed. Syrup of sugar, glucose or corn is used for fruits, and brine or salt solution for vegetables. The process of preparing these for different requirements, on commercial as well as domestic scale, are dealt with in this chapter.

### **SUGAR SYRUPS**

In canning fruits, sugar in the form of syrup is used to bring out the full flavour of the fruits, care being taken not to make the contents excessively sweet. Strength of the syrup would depend on the kind and variety of fruit. Generally, the more acidic fruits require denser syrups.

### **Preparation**

Syrups can be made either by the 'cold process' or by the 'hot process'. In the cold process, sugar is placed in a tank and cold water poured over it and stirred, The solution is then filtered through a thick flannel bag, muslin cloth, or fine brass wire gauze to remove insoluble impurities. Sometimes warm water may also be added to facilitate the dissolving of the sugar. In the hot process, sugar and water are placed in a steam jacketed kettle, boiled and the scum removed. The syrup is clarified further by nitration. Steam helps to sterilize the syrup and to prolong its keeping quality. The quantities of sugar and water required to prepare syrups of a given Brix are given in Table 1.

### **Testing Syrup Strength**

Uniformity of the canned product depends on the accuracy of measuring and increasing the syrup, because any mistake in syrup making cannot be rectified later. Since the cost of syrup forms an important item in the total cost of the finished product, it is essential to control the syrup strength and thereby avoid any wastage. Accurate thermometers and hydrometers are necessary for this. The different kinds of hydrometers used are the Brix or Balling, Baume, specific gravity and Twaddell hydrometers. A refractometer can also be more conveniently employed.

The Brix or Balling hydrometer gives directly the percentage of sugar by weight, in the syrup. It is calibrated at 20°C, and corrections are needed for other temperatures. On the Baume's hydrometer, the divisions range from 0 to .70 degrees. The relation between the Brix and Baume scales is given in Table 8. Specific gravity in the case of Baume's reading may be deduced by adopting the formula:

### **Syrup Calculations**

Sometimes, it will be found necessary in practice to dilute a syrup or increase its strength. This is facilitated by what is known as the 'square method'.

### **Fruit Beverages**

FRUITS most commonly used for preparing beverages are sweet orange, mandarin (*sangtra*) loose jacket orange, sour lime (*kagzi nimboo* or *limboo*), lemon, grape fruit, grape, apple, mango, pomegranate, *phalsa*, (*Grewia asiatica*), jamun (*Eugenia Jambolana*), mulberry, passion fruit, pineapple, etc. Tomato juice also has become quite popular. Among the squashes, sweetened orange juice known as orange squash, lemon squash and pineapple squash are the most popular ones.

### **Plum Squash**

Juicy plums like the *alucha plum* are preferred for the preparation of plum squash. To extract the colour from the skin, the plums are heated at 82°C for about 30 minutes, in half their weight of water. The heated fruit is passed through a pulper to extract juice. The juice is made into squash of 45 to 55 degrees Brix. Sodium benzoate is added as preservative.

### **Other Fruit Squashes**

Squashes and syrups can also be made from several other fruits like mulberry, raspberry, strawberry, pear, apricot, pumelo, guava, musk melon etc. The methods of preparation are broadly the same as those described in the case of orange, mango, pineapple, etc. Ingredients required can be deduced from basic principles involved in the preparation and preservation of squashes.

## **JUICES**

Pure fruit juices like orange juice, apple juice, pineapple juice, etc., which are highly prized as nutritive breakfast foods are packed in large quantities in several countries. Apple juice is generally bottled, while other juices are canned.

### **Apple Juice**

Unfermented apple juice is highly popular in Europe. In this country also, it is gaining popularity. With the increase in area under apples, the demand for apple juice is likely to increase in the near future. A method has been standardised for the preparation of juice from Kulu valley apples like the Yellow Newton and Baldwin varieties. The apples are washed with a weak solution of hydrochloric acid (22.7 litres of acid in



454 litres of water) to remove any arsenic and lead spray residues, and are then crushed in an apple grater to pieces of 0.3 cm to 1.2 cm size. The pieces are placed in a basket press and pressed to get the juice.

### **Cashew Apple Juice**

Cashew apples are available in large quantities on the West Coast, where there is a thriving cashew kernel processing industry. Large areas are being planted with cashew to meet the increasing world demand for the kernel. At present, the fruit, which is the fleshy portion to which the nut is attached, goes practically to waste. The fruit is highly perishable. It is fairly rich in vitamin C, and as such is worth preserving, by organising its collection and processing at convenient centres. The resulting sweetened juice has a pleasant taste and the characteristic aroma and flavour of the cashew apple.

### **Citrus Juices**

Among citrus juices, canned orange juice and frozed 4:1 orange juice concentrate are the most popular fruit juices on account of their nutritive avalue, vitamin C content and universal appeal in almost all countries. To retain the natural taste and flavour as well as vitamin C content of the juice highly sophisticated processing equipment and technique are employed.

To improve its quality and retain its vitamin C content, the juice is generally deaerated and flash-pasteurised. Preservation of orange in its pristine purity, with all its natural flavour, is still a technical problem. It develops a characteristic stale or off-flavour during storage.

By a suitable modification of the method of a extraction and preliminary treatment of the juice, it is possible to minimise the development of bitter taste in the preserved juice.

Modern equipment comprising of fruit washers, juice extractors, depulpers, deaerators, flash pasteurizers, fillers etc., have quite recently been installed in one or two factories in the country for canning orange juice and manufacture of high density (6:1) orange juice concentrate.

### **Grape juice**

Coloured as well as white grapes can be used for making grape juice. In the case of coloured varieties, it is necessary to heat the crushed berries for 10 to 15 minutes at 60 to 63°C to extract the colouring matter. White grapes are not heated. Juice is extracted from the crushed grapes by means of a basket press. The extracted juice is filtered through cloth and bottled by the 'over-flow' method. In the bottled juice, cream of tartar (*argol*) gradually settles down during storage.

### **Pineapple Juice**

As already mentioned earlier, pineapples are cultivated fairly extensively in Assam, West Bengal, Kerala and recently in Coorg. The production in this area is nearly 95 percent of the total production of pineapples in the country. Although there are a number of varieties, namely kew, giant Kew, Mauritius, Jaldhoop, Singapore, etc., Kew and Giant Kew are preferred for canning whereas other varieties can be used for preparation of juice. Pineapple juice is generally but not always a by-product in the canning of pineapples.

In the HTST process, the juice is quickly heated to 88°C, held at that temperature for 2 to 3 minutes, and then immediately filled into clean and steamed cans, which are closed, inverted for a minute or two and then cooled.

### **Pomegranate Juice**

The *kandhari* variety of pomegranate, which contains richly coloured purple grains, gives a highly delicious juice. The fruit is cut into quarters and the grains separated and pressed in a basket press. The juice can also be extracted from the cut quarters as such by applying gentle pressure in a basket press. The juice is filtered through thick cloth. It is then bottled and preserved by pasteurization or by addition of sodium benzoate. The flavour is rather delicate and becomes less intense gradually during prolonged storage. The juice can also be converted into an attractively coloured pleasant-tasting squash of 55 to 60 degrees Brix. The well-known syrup of grenadine is prepared from pomegranates.

## CARBONATED BEVERAGES

Use of fruit juices in the preparation of carbonated beverages was practically negligible till very recently, although large quantities of aerated water, iced *sherbets*, and synthetic drinks containing sweetening agents like saccharin, are consumed all over the country. These products have practically very little or of no nutritive value. If real fruit juices are popularised instead, the nutritive value of these beverages could be increased considerably which is a highly desirable objective.

To prepare orange syrup for carbonation, a heavy syrup is made by mixing 4.5 kg of orange juice, 6.8 kg of sugar and 198 g of citric acid. Of this, 42 to 56 g are filled into 283 to 340 g bottles for carbonation. Other syrups like those of pineapple, lemon, lime, etc. can also be prepared in a similar manner.

### Fermented Beverages

FERMENTED beverages have been known to mankind from times immemorial. Grape wine is the most important among these. The Vedic "*Soma Rasa*" also is a kind of fermented juice. Wines made from fruits are named after the particular fruit employed. Thus we have apple cider from apples, perry from pears and oranges. Starch and sugar also are fermented to get special types of liquors. In India, such liquors are known as *nira* juice of palm tree, sake from rice, country liquors from molasses etc.

### Grape Wine

**Raw Material.** Grapes intended for wine making are sorted to remove mouldy bunches and then crushed between fluted rolls. In the case of white grapes, the crushed mass is pressed directly in basket-type presses. In the case of coloured grapes, on the other hand, they are fermented slightly before pressing the juice. This helps in the extraction of colour and also facilitates pressing of the juice. Generally, the yield of juice is 60 to 70 per cent.

### Fermentation

To ferment the juice, which is popularly known as 'must' in fermentation industry, is a culture of pure wine yeastlike *Saccharomyces ellipsoideus* is added as a starter. Sulphur dioxide is added to the 'must' at the rate of 50 to 70 ppm (about 226 g of potassium metabisulphite per 1016 kg of grapes) to check the action of wild yeasts and bacteria which are undesirable in alcoholic fermentation. The temperature should be maintained between 27°C and 29°C. Fermentation virtually ceases at about 38°C.

Generally, the Brix of the majority of grape varieties grown in the country ranges from 12 to 16 degrees, except in the case of seedless Kishmish grapes, which have a Brix as high as 23 to 26 and, therefore, dry satisfactorily under atmospheric conditions. In the case of grapes of low Brix value, case sugar is added to the juice sometimes to raise the Brix to about 23 degrees.

During the maturation process, there is natural clarification of the wine. Filter aids, white of egg, etc, can also be employed to bring about the clarification.

### Jams, Jellies and Marmalades

AMONG preserved fruits, jams, jellies and marmalades form an important class of products. During World War II, fairly large quantities of these were imported into India from the U.S.A., the U.K., and Australia. Nowadays, such products are being manufactured extensively in several factories in this country, as by-products or joint products in fruit canning units. They are also made in many of the homes all over the country. Their production and demand can be increased manifold by making better use of cull fruit that is being wasted at present.

Marmalade is a fruit jelly in which the slices of the fruit or of the peel are suspended. The term 'marmalade' is generally associated with the product made from citrus fruits like oranges and lemons, in which shredded peel is included as the suspended material.

The term fruit jelly covers, in a general sense, jams and marmalades also which possess the consistency of jelly (whether made from clear juice or from pulp).

### Fresh Fruits

As pectin is the main ingredient in the fruit which gives a set to the jam, it is preferable to use some green fruit which is rich in pectin along with the ripe fruit to secure the desirable jellying effect in the jam. Over-ripe fruit should not be used as it produces pasty product. In some cases, where the fruit is deficient in pectin, pectin from other fruits or commercial liquid or solid pectin may be added to supplement it.

### **Fruits Preserved by Heat Treatment**

The fruit is prepared in the same way as for canning, and heated to a sterilizing temperature in hermetically sealed containers. Sometimes, a small quantity of sugar is also added to preserve the aroma, colour, and texture of the fruit. Plums, apricots, pineapples, and peaches are stored without addition of sugar whereas strawberries and raspberries are stored after adding sugar. The added sugar is taken into account at the time of making the jam. This method is not, however, generally used largely for the following reasons :

1. Difficulty of storing the fruit in barrels;
2. Loss of colour in fruits such as strawberries and raspberries during the treatment and subsequent storage;
3. A certain amount of loss of pectin while the fruit remains hot for a long period in bulk packing.

### **Sulphitation for Storing**

For preserving fruits in bulk, sulphur dioxide is universally employed in the form of sodium or potassium meta-bisulphite, sulphurous acid or calcium sulphite. Calcium sulphite provides an additional advantage in that it hardens the tissues of soft fruit and thereby prevents their disintegration.

Sulphur dioxide toughens the skin of some fruits such as gooseberries and red currants. These fruits should, therefore, be heated to boiling temperature and then cooled before adding SO<sub>2</sub>. This preliminary heating will destroy the enzyme in the fruit that would, otherwise, destroy the jellying power of the pectin present in the fruit.

### **Preparing the fruit for Jam-making**

The fruit is washed thoroughly to remove any adhering dust and dirt. Leaves, stalks and other undesirable portions are removed. The fruit is then subjected to preliminary treatment which varies with the type of fruit. For example, strawberries are crushed between rollers. Raspberries are steamed crushed and passed through sieves to remove the hard cores. Plums are heated with a small quantity of water until they become soft, and are then passed through a wide mesh sieve to separate the stones. Sometimes, the stones are not removed while making whole fruit plum jam. Cherries are treated in a similar way. Gooseberries are whirled in a rotary vertical cylinder lined with carborundum to rub off the tops and tails.

### **Addition of Sugar**

Sugar in excess of the requisite quantity should not be added because, if the percentage of total soluble solids becomes very high, the jam becomes gummy and sticky. In case excess of sugar has been added, the remedy lies in adding pectin or acid or both, to counteract the effect of excess sugar. If, on the other hand, the percentage of soluble solids is low and there is premature setting of the jam, indicating thereby that the material contains excess of pectin, it is advisable to add more sugar. Under exceptional circumstances where more sugar is not added, it would be desirable to add a small quantity of sodium bicarbonate to reduce the acidity and thus prevent pre-coagulation.

## **SOME TYPICAL JAMS AND JELLIES**

### **Jams**

**Apricot jam.** Both White and yellow apricots can be used for the preparation of apricot jam. The method is similar to that employed in the case of peach jam except that the quantity of acid added should be increased to 0.5 per cent, especially in the case of the sweeter white varieties. The kernels can be decuticled like almonds and added to the jam to improve its taste and appearance. Besides fresh apricots, sulphited apricot pulp packed in barrels during the fruit season and also dried apricots, are extensively employed for large-scale manufacture of apricot jam. Apricot jam is a popular product in several parts of the

country.

**Peach jam.** White as well as yellow peaches of free and also olingstone type are employed for the preparation of peach jam. The fruit is peeled with a knife or with lye solution, and the stones removed. The pulp is softened by heating it with about 1/4th its weight of water. An equal weight of sugar and 0.2 per cent citric or tartaric acid are added to get a jam having good taste, set and flavour.

**Pear jam.** Pears are peeled and cut into small pieces which are then crushed and boiled with 3/4th of their weight of water. To that pulp 0.25 to 0.5 per cent citric acid is added towards the end point of boiling the jam. Pear jam forms an important by-product in the canning of pears.

## **MARMALADES**

In the preparation of marmalades, all the conditions necessary for jelly-making are applicable. The pectin and acid contents of the marmalades should be kept slightly higher than what has been recommended for jellies. Citrus marmalades are generally of two kinds, namely sweet marmalade and bitter marmalade. The well-known English marmalades such as golden shred marmalades, are of the bitter type; bitterness being accepted as a desirable characteristic of the product. A mixture of sweet and bitter oranges like the Seville oranges is used in their preparation.

### **Flavouring**

It is desirable to add a small amount of flavour to the product, because most of the natural flavour volatilizes during the boiling and cooking processes. Generally, a small quantity of orange oil may be added to the marmalade at the time of filling into jars or cans.

### **Tomato Products**

FRESH tomatoes are highly refreshing and appetizing. They are a good source of vitamins, particularly vitamin C. In this country, tomatoes are grown both in summer and winter, but those grown in winter are superior because they contain more solids.

The tomato changes in colour during different stages of its maturity and ripening i.e., from green to pale-white, yellow and finally red. The yellow colour is owing to the presence of carotene. The red colour appears when the lycopene is formed in the fibres.

## **TOMATO JUICE**

For this product, only plant-ripened and fully red tomatoes should be used. All green, blemished and over-ripe fruits should be rejected as they adversely affect the quality of product. Juice got from over-ripe tomatoes is usually thin and not quite pleasant in its taste and aroma.

### **Washing and Trimming**

Mere rinsing of tomatoes in water is not enough, because mould filaments and other micro-organisms found in the cracks, wrinkles, folds and stem cavities, are not easily dislodged by gentle washing alone. For thorough cleaning, tomatoes should be washed in plenty of running water. For commercial production, rotary washers, or trough washers fitted with moving conveyor belt and soft roller brushes, are generally employed.

### **Crushing**

After trimming, tomatoes are cut into 4 to 6 pieces for boiling to soften the tissues. Alternatively, they may be crushed by means of fluted wooden roller-crushers.

## **TOMATO PASTE**

A concentrated tomato juice or pulp without skin and seeds, and containing not less than 25 per cent of tomato solids, is known as tomato paste. If the pulp is further concentrated so as to contain 33 per cent and more of tomato solids, it is called concentrated tomato paste. Common salt, basil leaf or sweet oil of basil leaf also may be added. Part of its acidity may be neutralized with sodium carbonate or bicarbonate.

Ordinarily, tomato juice can be concentrated to 14 to 15 per cent times solids in open pans, but for higher concentrations, vacuum pans are required. The initial concentration is generally carried out in open pans

and the product is then finished in vacuum pans.

As the product is very thick, the total solids in it are determined with an Abbe' refractometer.

### **TOMATO COCKTAIL**

Tomato cocktail is gaining popularity in many of the high class hotels and restaurants. It is prepared just before serving and sometimes is also served from stock. In the latter case, the cocktail is preserved by pasteurization in bottles. Although the recipes vary, the main constituent is tomato juice to which common salt, vinegar, Worcestershire sauce, lemon or lime juice, tabasco sauce etc., are added in different proportions to suit the palate.

### **TOMATO KETCHUP**

Tomato ketchup is a fairly common and popular tomato product in this country. It is made by concentrating tomato juice or pulp without seeds and pieces of skin. Spices, salt, sugar, vinegar, onion, garlic, etc., are added to the extent that the ketchup contains not less than 12 per cent tomato solids and 28 per cent total solids.

### **CHILLI SAUCE**

Chilli sauce is a highly spiced product which is prepared from plant ripened and peeled tomatoes. It is mostly used as a flavouring material in cooking, and also as a table relish to some extent.

#### **Preparation**

The tomatoes are washed thoroughly, rejecting any blemished or rotten portions. They are then blanched in hot water or in steam till the skin is loosened. They are then dipped in cold water to stop further cooking and softening. They are then peeled by lifting the peel easily by means of pointed end of a knife and chopped. The seeds are not removed. During cooking of the chopped material, spices are added, tied loosely in a muslin cloth bag, just as in the case of tomato ketchup.

#### **Chutneys, Sauces and Pickles**

CHUTNEYS, sauces and pickles of various kinds are prepared in Indian homes and also on a commercial scale. They find a ready market in many countries. Standard recipes have been modified to suit local taste in the country and consumer acceptability in other parts of the world. Fruits such as apple, peach, plum, apricot, and mango and vegetables like turnip, cauliflower, carrot, etc, are the basic raw materials. Onion, garlic, spices, herbs, etc., are added for flavour. Vinegar, common salt and sugar are also used to make the products more palatable. Vinegar serves as a preservative also to some extent.

#### **Cooking Process**

Sweet chutneys such as mango and apricot chutneys are generally cooked to consistency of jam to avoid fermentation of the product during storage. Where vinegar is used in fairly large quantities, the amount of sugar may be reduced correspondingly, because vinegar itself serves partly as a preservative.

#### **Bottling**

Only clean and dry bottles and jars earlier sterilized in boiling water should be used and they should be warm at the time of filling. If the bottles and the jars are not properly cleaned, fermentation is likely to set in through fermentation organisms adhering to the walls of the containers. It is safer to pasteurize the filled bottles and sealing them at 82°C for about 30 minutes in 0.45 kg size jars.

#### **Mango Chutney**

This is a typical product of India. For its preparation, slightly under ripe fruits of seedling varieties are preferable. Fresh as well as brined and peeled mango slices can be used in its preparation. Both types of raw material are employed by the industry. The latter is used to extend manufacture of chutney beyond the mango season. In this case, the slices are preserved in a brine of 15 per cent strength, the percentage of salt being maintained by adding salt from time to time. Some of the manufacturers prefer to add dry salt to the slices.

#### **Soya Sauce**

Soya sauce is made from soya beans. the sauce has usually a predominant saltish taste and has a dark brown colour. It is made by cooking soya beans and wheat, and when allowing the mass to undergo mould fermentation for 3 to 4 days. The mouldy mass is then mixed with strong brine (15 to 20 per cent) to form a mash which is filled into wooden barrels to bring about bacteriological and chemical changes in the presence of a high concentration of salt. In due course, a thick brown liquid is formed. It is boiled and filtered. To the filtered liquid, molasses are added to improve the flavour. the finished product, which is known as soya sauce, is bottled in the usual way.

## **SOUPS AND SOUP MIXES**

Ready-to-serve soups such as tomato soup, mushroom soup, mixed vegetable soup, especially dried vegetable mixtures for quick preparation of soups at home, are gaining popularity nowadays. Liquid soups are generally canned. They are warmed at the time of serving. In the case of typical soup, namely tomato soup, the following two recipes; one for home scale preparation and the other for commercial production will be useful as guidelines.

### **Fermentation in Brine**

Steeping of the vegetable in a salt solution of pre-determined concentration for a certain length of time is called brining. This type of treatment is adopted in the case of cucumbers and similar vegetables, which do not contain sufficient juice to form brine with dry salt.

#### **Brine Preparation**

Brine can be prepared by dissolving common salt in water and filtering it through jelly bags to remove insoluble impurities. The amount of brine necessary to cover the vegetable is usually equal to about half the volume of the material to be fermented. To be more precise, if a keg of 45.4 litres capacity is to be packed, the amount of brine required would be 22.7 litres. It is preferable to make the whole quantity of brine needed for the day in one lot.

## **VARIOUS PICKLES**

There are several kinds of pickles sold in the Indian market. Mango pickle ranks first. Then comes cauliflower and turnip pickles followed by those of lime, chilli, bamboo etc. Pickles are classified according to the method of their preparation.

Vinegar pickles are the most important ones in other countries. Their are sour, sweet, spiced and mustard pickles. Pickled onions occupy a prominent place among pickles imported into this country. Then come mixed pickles, followed by piccalilli, dill, walnut, beetroot, cabbage and all other kinds of pickles made from different fruits and vegetables.

#### **Bamboo Pickle**

Tender bamboo shoots can be used for preparing different types of pickles.

Select tender bamboo shoots and remove the outer leaves Cut the shoots into small pieces and boil them for half an hour twice with 2 to 3 changes of water to remove the poisonous bitter principle namely, hydrocyanic acid. Drain and rinse well. Dry the pieces for 2 to 3 hours in the sun. Mix them with the usual spices and a small quantity of rapeseed oil or gingelly oil. Fill them into a stone jar. Place the jar in the sun for about a week. To improve its keeping quality, add sufficient oil to keep the pieces fully covered.

#### **Vegetables Preparation for Processing**

Processing begins in the field for many vegetables. This is true with mobile cutters for greens, viner/shellers for peas and beans, juice extractors for tomatoes, and graders/washers for many vegetables. The advantages of such operations are that harvesting/processing can be stopped or started at any point to accommodate variations in the field; there is no lag in time in which freshly harvested, sometimes badly bruised, product can deteriorate while waiting for the next step in processing; and most of the refuse, including vines, shells, leaves and other organic waste, is scattered over the fields to be incorporated into

the soil. There are several steps common to the preparation of most vegetables for processing.

### **BASIC STEPS IN PREPROCESSING**

The operations involved in preprocessing vegetables for canning, freezing, dehydration, or pickling can be summarized as follows :

1. Harvest in the immature, tender stage, before any portion becomes fibrous and tough. Corn should be full grown, but tender; peas and beans should be "green" ; stalks of asparagus, stems of greens, and shells of snap beans should be without fiber. There is a tendency for most vegetables to be harvested after the peak of quality.
2. Grade to remove trash, overmature, diseased, insect-infested vegetables, and other materials that would impart an off-flavor to the product. This may be done with a roller-grader/sizer, a blower, or rod/shaker, followed by hand inspection. Bruising or cutting, which may cause loss of juices, should be avoided.
3. Weigh to ascertain pay rate, yield, and production rate.
4. Rinse in water to remove surface dirt, insects and small trash not removed by the blower. A detergent may be used on vegetables taken from the soil (e.g. potatoes, sweet potatoes, and turnips) and leafy vegetables (e.g. spinach and turnip greens), provided it is thoroughly rinsed off.
5. Prepare as required for individual vegetables. This includes peeling (beets, carrots, parsnips, potatoes, sweet potatoes); shelling (beans, lima beans, peas, blackeye peas); shucking (corn, cauliflower, Brussels sprouts); trimming (snap beans, okra, broccoli, and others as needed); and cutting and dicing (carrots, beets, sweet potatoes, okra, and others as desired).
6. Blanch or scald at 190°F (88°C) to stop all life processes and destroy yeast and mold; to inactivate enzymes that would cause discoloration and changes in flavor and aroma; to render the product limp and easier to pack in containers; to fix the green color; and to remove certain harsh flavors common in vegetables such as turnip greens, collards, spinach, okra, and snap beans.

### **PREPROCESSING OF TOMATOES**

Mechanical harvesting has aggravated the waste disposal problem and decreased yields below the potential. Even though plant breeders have developed tomatoes with tough skins and firm flesh, rough handling during mechanical harvesting still causes significant damage. Once damaged, tomatoes deteriorate rapidly because of microbiological and enzymatic actions. This causes a 10-20% loss in tomato solids during the usual 24 hr interval between harvest and factory processing, including an allowance for hauling mold losses. The damaged fruit ends up in urban waste and is a direct loss.

#### **Peeling**

**Lye Peeling.** Tomatoes can be lye-peeled by immersion in a high-volume machine using a principle successfully applied to fruits. In this procedure, a roller conveyor spreads tomatoes uniformly into machines, where they are picked up by travelling buckets on an endless conveyor that takes them through the immersion tank filled with 14-17% lye solution. A short time exposure at relatively high temperatures, combined with vigorous agitation, results in high skin-removal efficiency (87-90% removal) . Exposure time, temperature, and lye strength can be varied to give optimum results with the particular characteristics of the lot being peeled.

**Freeze Peeling.** A process of peeling tomatoes using low temperature short-time freezing was reported by Brown *et al.* and Anon. Liquid nitrogen (-196°C) is used as the refrigerant for freezing the skin and a thin layer of cells just beneath the skin. The fruit is immediately thawed, after which the skin is quickly and easily removed from the fruit.

**Peeling in Calcium Chloride Solution.** Another method of peeling tomatoes is by submerging them in a hot solution of calcium chloride (CaCl<sub>2</sub>). In this method, the underskin or mesocarp of the tomato is not removed; therefore, the finished product has a better appearance and color than product obtained by lye

peeling. Higher drained weights and original shape were obtained, and the firm whole tomatoes could be sliced in a manner similar to whole fresh tomatoes.

## **BLANCHING**

The purpose of blanching is to prepare vegetables for the next step in processing. There are many ways of doing this, depending upon the kind of vegetable and the end product desired. Many methods of blanching have been used in an attempt to reduce the leaching of nutrients and to get uniform heating throughout the product.

## **IRRADIATION OF VEGETABLES**

Since about 1945 considerable public monies have been invested in research on the use of irradiation to prevent postharvest losses in vegetables for the fresh market and processing. Early optimistic reports were based on results with stationary equipment. Extensive studies in California and elsewhere, employing actual and simulated transit equipment, have yielded largely negative results. Results show that conventional refrigeration is still the best means of reducing postharvest losses. Furthermore, refrigeration is cheaper, noninjurious, and more effective than irradiation.

## **Tomato Juice Blends**

Tomato juice blends were initially developed as a way to utilize vegetable juices that because of their high natural pH, required destructive high temperature sterilization procedures. Acidulation with organic acids would have been a logical way to use low-acid juices, except that vegetable juices with added appropriate acids apparently were not accepted by many consumers. Tomato juice, then, became the popular natural acidulant almost 30 years ago.

## **VEGETABLE SAUCES**

A sauce is the liquid element accompanying every culinary preparation. Although sauces are as numerous as they are varied, they can broadly be classified as (1) those comprising both the essential solid and liquid elements, such as stews containing vegetables and/or meat or (2) accompanying sauces, such as tomato sauce, white and brown sauces. The vegetables used in a sauce can be either fresh, canned, or dried. Special flavorings, including herbs and spices, and oil can be added to give special characteristics to a sauce.

## **Vegetable Dehydration**

Dehydration is an ancient method for preserving food. It lowers the costs of packaging, storing, and transportation by reducing both the weight and volume of the final product. Sun drying of certain fruits, such as apricots and peaches is common, whereas there is only limited application of sun drying with vegetables, except for a small quantity of come-dried mushrooms and experimental use of solar driers for carrots, celery, etc.

## **Costs of Dehydration**

A wide variety of methods is available for drying food products, each with a definite effect on the quality and physical properties of the product. Costs vary with drying methods, and they vary widely for different products made by the same drying method.

Although frozen peas are the least costly item to manufacture, its cost advantage disappears if the cost associated with one month of home storage is included. In that case, compressed freeze-dried peas is as equally cost-effective as its frozen counterpart.

## **Solar Drying**

Because of the tightening supplies and increasing costs of various forms of energy, the utilization of solar energy for drying vegetables has been evaluated. The use of wind and radiant solar energy in combination for drying vegetables can help promote conservation of food and energy resources.

## **TYPES OF DRIERS**

The common kinds of vegetable-drying equipment are tray, tunnel, continuous conveyor-belt, belt-trough,



air-lift, fluidized-bed, spray, drum and vacuum shelf.

Air drying of vegetables is still the most widely used method. In the early days, tunnel and cabinet driers were in general use, but continuous conveyor-belt driers and belt-trough driers are rapidly replacing these devices.

### **Tunnel Driers**

### **Continuous Conveyor Driers**

### **Pneumatic Conveying Driers**

### **Belt-Trough Driers**

### **Bin Driers**

### **Spray Driers**

### **Drum Driers**

### **Freeze Driers**

### **Freezing of Vegetables**

During the past decade, the growth of the frozen-food industry has been greater than that of any other segment of the food industry. Production value of frozen fruits and vegetables increased about 12%.

The most important vegetable crop preserved by freezing is the white potato. Other important frozen vegetables are green peas, corn, snap beans, broccoli, carrots, lima and green beans, and mixed vegetables. Cauliflower, onions, Brussels sprouts, and green asparagus are also frozen in significant quantities.

### **SUITABILITY OF VEGETABLES FOR FREEZING**

Vegetables were first successfully frozen commercially about 1936, with green peas and spinach as leaders. The key to holding the fresh flavor was not freezing *per se*, but inactivation of the flavor-deteriorating enzymes by blanching before freezing. Once this problem was solved, the list of commercially frozen vegetables grew to more than 25 by 1944, and by 1950 included most heat-tolerant vegetables.

Most of the early research on blanching and freezing vegetables was done at the U.S. Frozen Food Laboratory, Seattle, Washington. This research team moved to the Western USDA Utilization Laboratory, Albany, California after the latter was established.

Since deterioration is so rapid after harvesting, all vegetables harvested on a particular day should be processed on that day unless immediately refrigerated. For this reason, during the peak of the processing season, a high percentage of the crop is harvested, transported, and processed at night. Most of the steps in handling (e.g., inspection, grading, trimming, shelling, and washing) can be done better before the vegetables wilt.

The list of vegetables considered unsuitable for freezing continuously grows shorter as (a) methods of preparation for freezing are improved; (b) better knowledge is obtained about maintaining the color, flavor, aroma, and texture in vegetables before, during, and after freezing; (c) improvements are made in defrosting and serving frozen vegetables; (d) more vegetables are frozen in combinations with other products; and (e) more vegetables are fully cooked before freezing.

### **Freezing Methods**

Freezing may be accomplished in various ways. Common methods include air-blast and plate freezing of packaged vegetables, and air blast belt, fluidized bed, and liquid-contact freezing of vegetables before packaging.

Liquid-contact freezants can be classified into two types: (1) those operating at or below  $-73^{\circ}\text{C}$  and (2) those operating in the range of approximately  $-18^{\circ}\text{C}$  down to  $-29$  to  $-34^{\circ}\text{C}$ . Rasmussen and Olson refer to the former as *cryogens*; these include liquid nitrogen (LN), liquid air, and liquid or solid carbon dioxide. Dichlorodifluoromethane (R-12) has attracted much attention as a freezant for liquid-contact freezing. This

material boils at  $-30^{\circ}\text{C}$ , high compared with the cryogenics, but freezing rates are quite comparable. The use of brines for direct freezing has been reported to give better result than air blast freezing for IQF items. Several liquid-contact freezants have found some applications in the frozen food industry, but product quality vs. freezing costs with these methods, compared with more conventional freezing methods, continues to be debated, and equipment improvements are still being developed.

**Dehydrofreezing.** In dehydrofreezing, the product is partially dehydrated (a two- to threefold concentration) just before packaging and freezing. Preparation procedures (i.e. harvesting, handling, storage, washing, peeling, cutting, blanching, and cooling) for vegetables that are to be dehydrofrozen are similar to the conventional methods.

Dehydrofrozen products must be stored and transported in the same manner as other frozen foods. The advantages of dehydrofreezing over conventional freezing methods are (1) savings in packaging, shipping, and storage costs; (2) reduction in thawing and drip losses; and (3) increased freezing capacity. Dehydrofrozen vegetables are still very limited in production and are used only for the institutional and remanufacturing trades.

### **STABILITY AND QUALITY OF FROZEN VEGETABLES**

Freezing is one of the best approaches to preserving quality in vegetables. According to Olson and Dietrich, properly blanched, frozen and packaged vegetables, including cauliflower, green beans, peas, spinach, etc, can be kept at  $-29^{\circ}\text{C}$  for 5 years without measurable change in color, flavor, chemical constituents, and physical attributes. The same authors reported that properly blanched and packaged frozen vegetables are stable enough to maintain high quality from one harvest to another at  $-18^{\circ}\text{C}$ . However, rigorous evaluations by trained test panels can detect minor color and flavor deterioration in some frozen vegetables stored at  $-18^{\circ}\text{C}$  for 1 year in comparisons with identical lots stored at  $-29^{\circ}\text{C}$ .

### **BEANS, GREEN**

The 'Blue Lake' cultivar of green beans (*Phaseolus vulgaris L.*) which is a pole bean type, is considered highly desirable for freezing. It yields 9-10 tons/acre, whereas bush bean cultivars usually yield 1-4 tons. However, the labor cost of growing and harvesting 'Blue Lake' pole beans is comparatively high, and in recent years, because of the development of mechanical harvestors for bush beans, many acres have been switched to bush types. Some principal bush-type green bean cultivars grown in the West are 'Tendercrop', 'Cascade', 'Asgrow 274', and 'Cornelli' 14'. The Italian green bean, or 'Romano' cultivar, has become increasingly important in recent years.

The size graded beans are fed into snippers, which remove the stems and most blossom ends from the pods. Some processors prefer to snip beans before size grading. Beans to be used for cuts pass to mechanical cutters where they are cross cut to lengths of 2.54-3.81 cm. Beans to be used as boil-in-bag items are frequently cut diagonally, at a 45-degree angle. Nubbins and small pieces are removed as the cut beans pass over a series of vibrating screens. After the cutting operations, beans are blanched in steam or in water at  $99^{\circ}\text{C}$  for 2-3 min. The large No. 5 and 6 beans used for French cut are first blanched and then cut. Although smaller beans can also be cut after blanching, a technique that reduces the flavor loss encountered when cut beans are blanched, this practice frequently leads to sanitation problems. In either case, the product is quickly cooled after blanching, then sorted, packed, and frozen. Cross-cut beans are frequently individually quick-frozen on belts or frozen by immersion in Refrigerant-12, and then bulk-stored.

### **POTATOES**

More than 75% of frozen potato products are used by restaurants and institutions. Because of the dominance of this one vegetable in total frozen vegetable pack, considerable space is devoted here to the principal form, the frozen French fry.

Frozen potato products are not only convenient but also dependable in quality. The use of frozen potato products, rather than fresh potatoes, has several advantages, especially for institutional and foodservice operations. These advantages include stable price, greater flexibility in meal preparation, simplification of storage and inventory control, uniform quality and reduced labor cost.

### **Storage Before Processing**

Potatoes are usually suitable for processing into frozen French fries immediately after harvest, but a buildup of reducing sugars during prolonged storage below 4°C may render many cultivar unsuitable for processing. If potatoes are used within a few months after harvest, storage at 4-10°C should permit production of a high-quality French-fried product. However, French fries prepared from potatoes stored for 2-3 months at 10-16°C have been reported to have better texture, flavor, and color than those prepared from potatoes stored below 10°C.

Potatoes are stored at 4°C or lower in many commercial storage cellars to minimize sprouting, withering, and spoilage. Under these conditions reducing sugars tend to accumulate. If the concentration of reducing sugars becomes excessive, the resulting French fries will be too dark in color. In such instances, potatoes must be conditioned before processing, i.e. held at 21°C or higher for 1-3 weeks just prior to use. This treatment lowers the reducing sugar content, but at the cost of weight losses due to shrinkage. It is generally recognized that a reducing sugar content above 2-3% of the potato solids is undesirable.

### **Blanching**

French fry strips are usually water-blanching before frying. Blanching makes product color more uniform, reduces fat absorption by gelatinizing the surface layer of starch, reduces frying time, and improves texture. Adjustments are made in blanching time and temperature to accommodate the variations encountered in different lots of raw material. Blanching may be done at 90°C in water for 10 min. It is common to operate two blanchers in series for greater flexibility. The first blancher may be used, for example, in the manner just described, while the second may contain a dilute sugar concentration to a level that gives a product with the best color on frying. Various compounds, such as calcium lactate for improvement of texture and sodium acid pyrophosphate for control of after-cooking darkening, have been used with varying success.

### **Frying**

After blanching, excess moisture is removed from the strips by dewatering screens and warm-air blowers before the strips are fed into a fryer at a carefully regulated rate. Various types of conveyors are used to carry strips through the hot fat at 121-191°C. In one method strips are conveyed through the fat in perforated trays or baskets mounted on an endless chain. Close attention to and control of frying conditions are essential in order to obtain a product that has the desired surface color and internal textural characteristics required for institutional use or home consumption. Restaurants, for example, desire French fries that can be prepared as needed by finish-frying in deep fat to develop color and crispness. To meet this need, the processor gives the strips a minimum of frying, i.e. "par-fries" them. Products destined for home consumption are fried more completely.

### **Other Products**

A wide variety of frozen potato products is made from the slivers and nubbbins from the French fry line and from chopped or sliced small potatoes. These include whole, diced, mashed, hash-browned, au gratin, O'Brien, cottage-fried, stuffed, home-fried, rissole, and Delmonico potatoes, potato pancakes, and other products.

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