SCHOOL OF BIO AND CHEMICAL

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – I – FOOD TECHNOLOGY – SCH1609

FOOD PROCESS ENGINEERING-FUNDAMENTALS

Food processing is seasonal in nature, both in terms of demand for products and availability of raw materials. Most crops have well established harvest times – for example the sugar beet season lasts for only a few months of the year in the UK, so beet sugar production is confined to the autumn and winter, yet demand for sugar is continuous throughout the year. Even in the case of raw materials which are available throughout the year, such as milk, there are established peaks and troughs in volume of production, as well as variation in chemical composition.

Availability may also be determined by less predictable factors, such as weather conditions, which may affect yields, or limit harvesting.

In other cases demand is seasonal, for example ice cream or salads are in greater demand in the summer, whereas other foods are traditionally eaten in the winter months, or even at more specific times, such as Christmas or Easter.

In an ideal world, food processors would like a continuous supply of raw materials, whose composition and quality are constant, and whose prices are predictable. Of course this is usually impossible to achieve.

In practice, processors contract ahead with growers to synchronise their needs with raw material production.

The basic physical characteristics of foodsand food products

Since the physical characteristics of plant and animal food materials affect how they are to be processed, handled, stored, and consumed, knowledge of these characteristics are important to engineers, processors and food scientists, plant and animal breeders, and other scientists.

The following provides a list of various properties-

1.1 Physical Characteristics

1. Shape

2. Size

3. Weight

4. Volume

5. Surface area

6. Density

7. Porosity

8. Color

9. Appearance

10. Drag coefficient

11. Center of gravity

1.2 Mechanical Properties

1. Hardness

2. Compressive strength

3. Tensile strength

4. Impact resistance

5. Shear resistance

6. Compressibility

7. Sliding coefficient of friction

8. Static coefficient of friction

9. Coefficient of expansion

a. moisture

b. thermal

10. Elasticity

11. Plasticity

12. Bending strength

13. Aerodynamic properties

14. Hydrodynamic properties

1.3 Properties of Raw Food Materials

- The selection of raw materials is a vital consideration to the quality of processed products.
- The quality of raw materials can rarely be improved during processing and, while sorting and grading operations can aid by removing oversize, undersize or poor quality units,
- It is vital to procure materials whose properties most closely match the requirements of the process.
- Quality is a wide-ranging concept and is determined by many factors.
- It is a composite of those physical and chemical properties of the material which govern its acceptability to the ‘user’ (the final consumer, or the food processor).
- Geometric properties, colour, flavour, texture, nutritive value and freedom from defects are the major properties likely to determine quality.
- An initial consideration is selection of the most suitable cultivars in the case of plant foods (or breeds in the case of animal products).
- Other preharvest factors (such as soil methods and postharvest conditions, maturity, storage and postharvest handling also determine quality.
- The timing and method of harvesting are determinants of product quality. Manual labour is expensive, therefore mechanised harvesting is introduced where possible. Cultivars most suitable for mechanised harvesting should mature evenly producing units of nearly

equal size that are resistant to mechanical damage.

- Uniform maturity is desirable as the presence of over-mature units is associated with high waste, product damage, and high microbial loads, while under- maturity is associated with poor yield, hard texture and a lack of flavour and colour.
- For economic reasons, harvesting is almost always a ‘once over’ exercise, hence it is important that all units reach maturity at the same time.
- The prediction of maturity is necessary to coordinate harvesting with processors’ needs as well as to extend the harvest season.
- It can be achieved primarily from knowledge of the growth properties of the crop combined with records and experience of local climatic conditions.
- For more severe processing, including heat preservation, drying or freezing, the quality characteristics may change markedly during processing. Hence, those raw materials which are preferred for fresh consumption may not be most appropriate for processing.

For example,

- ➢ succulent peaches with delicate flavour may be less suitable for canning than harder, less flavoursome cultivars, which can withstand rigorous processing conditions.
- ➢ Similarly, ripe, healthy, well coloured fruit may be perfect for fresh sale, but may not be suitable for freezing due to excessive drip loss while thawing.

1.4 Raw Material Properties

Geometric Properties

- Food units of regular geometry are much easier to handle and are better suited to high speed mechanised operations. In addition, the more uniform the geometry of raw materials, the less rejection and waste will be produced during preparation operations such as peeling, trimming and slicing.

For example,

- ➢ Potatoes of smooth shape with few and shallow eyes are much easier to peel and wash mechanically than irregular units. Smooth-skinned fruits and vegetables are much easier to clean and are less likely to harbour insects or fungi than ribbed or irregular units.
- Agricultural products do not come in regular shapes and exact sizes. Size and shape are inseparable, but are very difficult to define mathematically in solid food materials. Geometry is, however, vital to packaging and controlling fill-in weights.

for example

- ➢ It may be important to determine how much mass or how many units may be filled into a square box or cylindrical can.
- Size and shape are also important to heat processing and freezing, as they will determine the rate and extent of heat transfer within food units.
- Uniformity of size and shape is also important to most operations and processes. Process control to give accurately and uniformly treated products is always simpler with more uniform materials.

- ➢ it is essential that wheat kernel size is uniform for flour milling.
- The presence of geometric defects, such as projections and depressions, complicate any attempt to quantify the geometry of raw materials, as well as presenting processors with cleaning and handling problems and yield loss. Selection of cultivars with the minimum defect level is advisable.
- There are two approaches to securing the optimum geometric characteristics: firstly the selection of appropriate varieties, and secondly sorting and grading operations.

1.5 Colour

- Colour and colour uniformity are vital components of visual quality of fresh foods and play a major role in consumer choice. However, it may be less important in raw materials for processing.

- For low temperature processes such as chilling, freezing or freeze-drying, the colour changes little during processing, and thus the colour of the raw material is a good guide to suitability for processing.
- For more severe processing, the colour may change markedly during the process. Green vegetables, such as peas, spinach or green beans, on heating change colour from bright green to a dull olive green. This is due to the conversion of chlorophyll to pheophytin.
- There are two approaches: i.e. procuring raw materials of the appropriate variety and stage of maturity, and sorting by colour to remove unwanted units.

1.6 Texture

- The texture of raw materials is frequently changed during processing. Textural changes are caused by a wide variety of effects, including water loss, protein denaturation which may result in loss of water-holding capacity or coagulation, hydrolysis and solubilisation of proteins.
- Raw materials must be chosen so that the texture of the processed product is correct, such as canned fruits and vegetables in which raw materials must be able to withstand heat processing without being too hard or coarse for consumption.
- Texture is dependent on the variety as well as the maturity of the raw material and may be assessed by sensory panels or commercial instruments. One widely recognised instrument is the tenderometer used to assess the firmness of peas

1.7 Flavour

- Flavour is a rather subjective property which is difficult to quantify. Again, flavours are altered during processing and, following severe processing, the main flavours may be derived from additives.
- Hence, the lack of strong flavours may be the most important requirement. In fact, raw material flavour is often not a major determinant as long as the material imparts only those flavours which are characteristic of the food.

- Flavour is normally assessed by human tasters, although sometimes flavour can be linked to some analytical test, such as sugar/acid levels in fruits.

1.8 Functional Properties

- The functionality of a raw material is the combination of properties which determine product quality and process effectiveness. These properties differ greatly for different raw materials and processes, and may be measured by chemical analysis or process testing.

For example,

- a number of possible parameters may be monitored in wheat. Wheat for different purposes may be selected according to protein content. Hard wheat with 11.5–14.0% protein is desirable for white bread and some wholewheat breads require even higher protein levels, 14–16%.
- Similar considerations apply to other raw materials. Chemical analysis of fat and protein in milk may be carried out to determine its suitability for manufacturing cheese, yoghurt or cream.

1.9 Deterioration of Raw Materials

All raw materials deteriorate following harvest, by some of the following mechanisms:

- Endogenous enzymes: e.g. post-harvest senescence and spoilage of fruit and vegetables occurs through a number of enzymic mechanisms, including oxidation of phenolic substances in plant tissues by phenolase (leading to browning), sugar-starch conversion by amylases, postharvest demethylation of pectic substances in fruits and vegetables leading to softening tissues during ripening and firming of plant tissues during processing.
- Chemical changes: deterioration in sensory quality by lipid oxidation, nonenzymic browning, breakdown of pigments such as chlorophyll, anthocyanins, carotenoids.
- Nutritional changes: especially ascorbic acid breakdown.
- Physical changes: dehydration, moisture absorption.
- Biological changes: germination of seeds, sprouting.

- Microbiological contamination: both the organisms themselves and toxic products lead to deterioration of quality, as well as posing safety problems.

1.10 Damage to Raw Materials:

Damage may occur at any point from growing through to the final point of sale.

It may arise through external or internal forces.

- External forces result in mechanical injury to fruits and vegetables, cereal grains, eggs and even bones in poultry. They occur due to severe handling as a result of careless manipulation, poor equipment design, incorrect containerisation and unsuitable mechanical handling equipment. The damage typically results from impact and abrasion between food units, or between food units and machinery surfaces and projections, excessive vibration or pressure from overlying material. Increased mechanisation in food handling must be carefully designed to minimise this.
- Internal forces arise from physical changes, such as variation in temperature and moisture content, and may result in skin cracks in fruits and vegetables, or stress cracks in cereals.
- Either form of damage leaves the material open to further biological or chemical damage, including enzymic browning of bruised tissue, or infestation of punctured surfaces by moulds and rots.

1.11 Improving Processing Characteristics

- Selective breeding for yield and quality has been carried out for centuries in both plant and animal products. Until the 20th century, improvements were made on the basis of selecting the most desirable looking individuals, while increasingly systematic techniques have been developed more recently, based on a greater understanding of genetics.
- The targets have been to increase yield as well as aiding factors of crop or animal husbandry such as resistance to pests and diseases, suitability for harvesting, or development of climate-tolerant varieties (e.g. cold-tolerant maize, or drought-resistant plants).

- Raw material quality, especially in relation to processing, has become increasingly important.

Selective Plant Breeding

- There are many examples of successful improvements in processing quality of raw materials through selective plant breeding, including:

➢ Improved oil percentage and fatty acid composition in oilseed rape;

➢ Improved milling and malting quality of cereals;

➢ High sugar content and juice quality in sugar beets;

➢ Development of specific varieties of potatoes for the processing industry, based on levels of enzymes and sugars, producing appropriate flavour, texture and colour in products, or storage characteristics;

➢ Brussels sprouts which can be successfully frozen.

- Similarly traditional breeding methods have been used to improve yields of animal products such as milk and eggs, as well as improving quality, e.g. fat/lean content of meat. Again the quality of raw materials in relation to processing may be improved by selective breeding. This is particularly applicable to milk, where breeding programmes have been used at different times to maximise butterfat and protein content, and would thus be related to the yield and quality of fat- or proteinbased dairy products. Furthermore, particular protein genetic variants in milk have been shown to be linked with processing characteristics, such as curd strength during manufacture of cheese. Hence, selective breeding could be used to tailor milk supplies to the manufacture of specific dairy products.

1.12 Genetic engineering

☐ Traditional breeding programmes will undoubtedly continue to produce improvements in raw materials for processing, but the potential is limited by the gene pool available to any species.

☐ Genetic engineering extends this potential by allowing the introduction of foreign genes into an organism, with huge potential benefits. Again many of the developments have been aimed at agricultural improvements, such as increased yield, or introducing herbicide, pest or drought resistance, but there is enormous potential in genetically engineered raw materials for processing.

- The following are some examples which have been demonstrated:
- tomatoes which do not produce pectinase and hence remain firm while colour and flavour develop, producing improved soup, paste or ketchup;
- potatoes with higher starch content, which take up less oil and require less energy during frying;
- canola (rape seed) oil tailored to contain:

(a) high levels of lauric acid to improve emulsification properties for use in confectionery, coatings or low fat dairy products,

(b) high levels of stearate as an alternative to hydrogenation in manufacture of margarine,

(c) high levels of polyunsaturated fatty acids for health benefits;

- wheat with increased levels of high molecular weight glutenins for improved bread making performance;
- fruits and vegetables containing peptide sweeteners such as thaumatin or monellin;
- 'naturally decaffeinated' coffee.

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1.16 What are Food Additives?

The pursuit of happiness through the enjoyment of food is a centuries old human endeavor. Taste, texture, freshness and eye appeal are major contributors to such enjoyment, made possible in our modern lifestyle through the use of highly specialized ingredients known as food additives.

The broadest practical definition of a food additive is any substance that becomes part of a food product either directly or indirectly during some phase of processing, storage or packaging.

Direct food additives are those that have intentionally been included for a functional purpose by the food processor, whereas indirect additives are those migrating into food products in very small quantities as a result of growing, processing or packaging.

Food additives afford us the convenience and enjoyment of a wide variety of appetizing, nutritious, fresh, and palatable foods. Their quantities in food are small, yet their impact is great. Without additives, we would be unfortunately lacking in the abundant and varied foods that we enjoy today.

Food Additives – Ingredients with a Purpose Direct food additives serve four major purposes in our foods:

1.17 Food Additives – Ingredients with a Purpose

1. To provide nutrition – to improve or maintain the nutritional quality of food. For example, the addition of iodine to salt has contributed to the virtual elimination of simple goiter. The addition of Vitamin D to milk and other dairy products has accomplished the same thing with respect to rickets. Niacin in bread, cornmeal and cereals has helped eliminate pellagra, a disease characterized by central nervous system and skin disorders. Other nutritional food additives (such as thiamine and iron) are used for further fortification in the diet and as a result, diseases due to nutritional deficiencies, common in lesser developed countries, are now very rare in the United States.

2. To maintain product quality and freshness – fresh foods do not stay that way for long periods of time; they rapidly deteriorate, turn rancid and spoil. Food additives delay significantly this deterioration and prevent spoilage caused by growth of microorganisms, bacteria and yeast and also by oxidation (oxygen in air coming into contact with the foods). For example, if you were to cut slices of fresh fruits such as apples, bananas or pears, they would rapidly turn brown as a result of this oxidation process. However, placing these slices in juice from lemons, limes or oranges can stop this process. Food processors do the same thing by using ascorbic acid – the principal active ingredient in citrus juice – when packaging fruit slices. Propionates, which naturally occur in cheese, are used similarly in bakery goods to prevent the growth of molds.

3. To aid in the processing and preparation of foods – additives impart and/or maintain certain desirable qualities associated with various foods. For example, we expect salad dressings to stay mixed once they have been shaken. Emulsifiers such as lecithin from soybeans maintain mixture and improve texture in dressings and other foods. They are used in ice cream where smoothness is desired, in breads to increase volume and impart fine grain quality, and in cake mixes to achieve better consistency. Pectin, derived from citrus peels and used in jellies and preserves when thickening is desired, belongs in the category of stabilizers and thickeners. Leaveners used to make breads, biscuits and rolls rise, include yeast, baking powder and baking soda. Humectants, like sorbitol that naturally occurs in apples, are used when moisture retention is necessary, such as in the packaging of shredded coconut.

4. To make foods appealing – the majority of food additives are most often used for this purpose. Unless foods look appetizing and appeal to our senses, they will most likely go uneaten and valuable nutrients will be lost. Food additives such as flavoring agents and enhancers, coloring agents and sweeteners are included by food processors because we demand foods that look and taste good.

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- Foods are concentrated for many of the same reasons that they are dehydrated; concentration can be a form of preservation but this is true only for some foods.
- Nearly all liquid foods which are dehydrated are concentrated before they are dried because
    - In the early stages of water removal , moisture can be more economically removed in highly efficient evaporators than in dehydration equipment.
    - Increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.
    - Some concentrated foods are desirable components of diet in their own right. For example, concentration of fruit juices plus sugar yields jelly.
    - Many concentrated foods, such as frozen orange juice concentrate and canned soups , are easily recognized because of need to add water before they are consumed.

2.1 More common concentrated foods include evaporated and sweetened condensed –

- Milks
- Fruits and vegetable juices
- Nectars
- Sugar syrups and flavored syrups
- Jams and jellies
- Tomato paste and

many type of fruit purees made by bakers , candy makers etc.

Benefits:

- Concentration reduces weight and volume and results in immediate economic advantages.
- It is prior to concentrate the liquid food before dehydration because in the early stages of water removal, moisture can be more economically removed in highly efficient evaporators than in dehydration equipment.

- Increased viscosity from concentration often is needed to prevent liquids from running off drying surfaces or to facilitate foaming or puffing.
- Concentrated forms have become desirable components of diet in their own right.

2.2 Methods of concentration

Solar concentration

- Uses solar energy
- Used to derive salt from seawater in earlier times
- Being practiced today in united states in manmade lagoons
- Slow process and suitable only for concentrating salt solutions

2.3 Open Kettles

- Heated by steam
- Being used for some jellies and jams for certain types of soups
- High temperatures and long concentration times causes damage to food
- Thickening and burn on of product to cattle wall gradually lower the efficiency of heat transfer and slow concentration process
- Widely used in manufacture of maple syrup

2.4 Flash Evaporators

- Subdivides food material and brings it into direct contact with the heating medium to speed up concentration process.
- Superheated steam at 150°C is used

2.5 Food Freezing & Product Quality

- An unfrozen product could have 70% water and 30% total solids. Within a temperature range of 5 degrees below the initial freezing point, a product might have 30% unfrozen water, 40% ice or frozen water, and the same 30% total solids. The changes occur gradually, As the temperature continues to decrease, the percentage of water in the frozen state increases.

2.6 Influence of Freezing Rate

- In slow rate freezing, ice crystals will become much larger.
- The movement of water from one cell to another leads to dehydration of the cell and irreversible changes .
- Large ice crystals within the product will lead to a frozen product with a rough texture.
- But extremely high freezing rates lead to stress cracking .

2.7 Storage of frozen foods

- The quality of a frozen-food is influenced by storage conditions. The changes in quality decrease as temperature is decreased, maintaining low storage temperatures increases the cost of frozen-food storage. Higher temperatures in frozen-food storage must be avoided due to the sensitivity of the frozen-food to temperature. Experience

  has established that a frozen food storage temperature of -18℃ is accepted as a safe storage temperature for extended shelf life of a frozen food.

Changes in quality

- Microbial activity (negligible at-18C)
- Biochemical reaction
- Enzymatic reaction (blanching for vegetables, sulfur dioxide/reduction of oxygen/addition of acid for fruits)

  Some of Specific Quality Attributes as Evaluating Factors
- 1. Degradations of pigments
- 2. Loss of vitamins
- 5. Enzyme activity
- 4. Oxidation of lipids

2.8 Fluctuation of Storage temperature on Product Quality

- An increase in the product temperature results in conversion of ice to liquid state, with the possibility of re-crystallization when the temperature decreases. Small ice crystals will tend to melt as the temperature rises and change back to ice when the temperature is lowered. The re-crystallization results in an increase in ice crystal size and the impacts on quality.

  Types of re-crystallization
- Isomass, a change in shape of the ice crystal resulting in a reduction of the surface-to-volume ratio
- Accretive, the joining of two ice crystals to form a much larger crystal
- Migration, an increase in size of crystals and an overall reduction in the number of ice crystals as a result of liquid water migrating from one crystal to another

2.9 Freezer Burn

- Reduced air temperature in the frozen-food storage environment is at a very low relative humidity. This creates a significant vapor pressure gradient between frozen product surface and the surrounding low-temperature air. A loss of moisture from the product surface and a negative quality impact occurs.

  Shelf Life of Frozen Foods
- Practical storage life (PSL)
- High quality life (HQL)
- Just noticeable difference (JND)
- Has to be organized to produce the right quantity of food at the correct standard, for the required number of people on time, using the resources of staff, equipment and material effectively and efficiently.

- The requirements of the production system have to be clearly matched to the type of food that is to be prepared, cooked an served, to the required market at the correct price.
- Many food production operations are based on the process approach, as opposed to PARTIE system (product approach).
- PARTIE system approach concentrates on the specific techniques and processes of food production.
- A whole range of different cuisines are able to fit more neatly into this approach because the key elements focus on the process, the way the food is prepared, processed, stored and served.
- Using this approaches, food production systems may be identified using the input/process/output model
- Conventional Method
  - Traditional Parties Method
  - Conventional Production with Convenience Food
- Centralized Production Methods
- Cook-Chill Production
- Cook-Freeze Production
- Sous vide

- The majority of food is purchased raw, very little for convenience foods.
- Labor is intermittent, rising to peak just before the service of each meal.
- This is an expensive way of running a kitchen; because of the manpower needed to operate it, its space, equipment and energy requirements
- Mostly are the same as traditional method production, but for this method they introduced a convenience foods with rang from partial to a virtually complete reliance.
- Involve the separation of the production and service components.
- Food that is centrally produced is either then distributed to the point of service in batches or is pre-portion; it may be transported in a ready-to-serve state.

- Food production storage and regeneration method utilizingprinciple of low temperature control to preserve qualities of processed foods.
- Low temperature conditions above freezing point, 0-3 C.
- Reheating immediately before consumption.
- Require low capital investment and minimum staff.
- Cook-chill, the process of food production, packaging, rapid chilling and storage under controlled refrigeration, is most commonly used in high-volume institutional settings. Its advantages can benefit all types of operations, though, especially banquet kitchens, recreational facilities, commissaries and hotels.
- Production, storage and regeneration method utilizing principle of freezing to control and preserve qualities of processed foods.
- Required special processes to assist freezing e.g. sauces reheat when needed
- Require high speed low temperature at least -20 C w/in 90 mins
- Good portion control and reduced waste.
- No overproduction.
- Central purchasing - bulk-buying discounts.
- Full utilisation of equipment.
- Full utilisation of staff time.
- Overall saving in staff.
- Saving on equipment, space and fuel.
- Fewer staff with better conditions- no unsocial hours, no weekend work, no overtime.
- Simplified delivery to units- less frequent.
- Solve problem of moving hot food. (EC regulations forbid the movement of hot food unless the temperature is maintained over 65°C (149°F).
- Maintaining 65°C is regarded as very difficult to achieve and high temperatures inevitably will be harmful to foods.)

For the Customer

- Increased variety and selection.
- Improved quality, with standards maintained.
- More nutritious foods.
- Services can be maintained at all times, regardless of staff absences.
- The advantages of cook-freeze over cook-chill are:
- Seasonal purchasing provides considerable savings.
- Delivery to units will be far less frequent.
- Long-term planning of production and menus becomes possible.
- Less dependent on price fluctuations.
- More suitable for vending machines incorporating microwave.

- Regeneration systems are simpler: infrared and steam convection ovens are mostly used and only approximately 12 minutes is required to reheat allfoods perfectly.
- Thawing time is eliminated.
- Smaller-capacity storage is required:3-4 days' supply as opposed to up to 120 days.
- Chiller storage is cheaper to install and run than freezer storage.
- Blast chillers are cheaper to install and run than blast freezers.
- Cooking techniques are unaltered (additives and revised recipes ar needed for freezing).
- All foods can be chilled so the range of dishes is wider (some foods cannot be frozen). Cooked eggs, steaks and sauces such as hollandaise can be chilled (after some recipe modification where necessary).
- No system is too small to adapt to cook-chill.

- Method of production, storage and regeneration utilizing principle of sealed vacuum to control and preserve the quality of processed foods.
- Individual portions of prepared food are placed in a special plastic pouches.
- Sous-vide is a form of cook-chill: a combination of vacuum sealing in plastic pouches, cooking by steam and then rapidly cooking and chilling. The objective is to rationalise kitchen procedures without having a detrimental effect on the quality of individual dishes.
- Vacuum pressures are as important as the cooking temperatures with regard to weight loss and heat absorption. The highest temperature used in sous-vide

cooking is 100°**C** (212°**F) and 1000 millibars is the** minimum amount of vacuum pressure used.

- As there is no oxidation or discoloration it is ideal for conserving fruits, such asapples and pears, for example pears in red wine, fruits in syrup. When preparing meats in sauces the meat is pre-blanched and then added to the completed sauce.
- Sous-vide is a combination of vacuum sealing, tightly controlled en papillote cooking and rapid chilling.

Potential users are brasseries, wine bars, airlines, private hospitals and function foodservice operators seeking to provide top quality with portion convenience.

2.10 The advantages of the sous-vide process are:

- Long shelf-life, up to 21 days if refrigerated.
- Ability to produce meals in advance means better deployment of staff and skills.
- Vacuum-packed foods can be mixed in cold store without the risk of cross- contamination.
- Reduces labour costs at point of service.
- Beneficial cooking effects on certain foods, especially moulded items and pates. Reduced weight loss on meat joints.
- Full flavour and texture are retained as food cook in its own juices.
- Economises on ingredients(less butter, marinade).
- Makes pre-cooking a possibility for a la carte menus.
- Inexpensive regeneration.
- Allows a small operation to set up bulk production.
- Facilitates portion control and uniformity of standards.
- Has a tenderizing effect on tougher cuts of meat and matures game without dehydration

2.11 Its disadvantages are:

- Extra cost of vacuum pouches and vacuum-packing machine.
- Unsuitable for some meats (for example, fillet steak) and vegetables which absorb colour.

- All portion in a batch must be identically sized to ensure even results.
- Most dishes require twice the conventional cooking time.
- Unsuitable for large joints as chilling time exceeds 90 minutes.
- Complete meals (for example, meat and two vegetables) not feasible- the meat com- ponent needs to be cooked and stored in separate bags.
- Extremely tight management and hygiene controls are imperative.
- Potentially adverse customer reaction (boil-in-the-bag syndrome).

2.12 Radiations

- Radiation is an energy form travelling through space (radiant energy) in a wave pattern and can be either naturally occurring (e.g. from the sun or rocks) or produced by man made objects (e.g. microwaves and television sets).
- waves produced by different sources distinguishes the different types and functionality of radiation, with high frequency radiation of UV, X-rays and gamma-rays posing the most significant risk to human health

2.13 Ionising and Non-ionising radiations

- Radiation is called ionising radiation when it is at a sufficiently high frequency (gamma rays and X-rays) that it results in the production of charged particles (ions) in the material that it comes in contact with.
- Ionising radiation has higher energy high enough to change atoms by knocking an electron from them to form an ion, but not high enough to split atoms and cause exposed objects to become radioactive. Therefore, the sources of radiation allowed for food processing cannot make food radioactive.
- Non-ionising radiation, such as that from microwaves, does not produce ions but can create heat under moist conditions and is routinely used for purposes such as cooking and re-heating of foods.
- Electric power, radio and television, microwaves, and light have lower energies. They cause molecules to move, but they cannot structurally change the atoms in those molecules.

2.14 Irradiation

- Food irradiation facilities that are built and maintained to accepted standards are no more hazardous than hospitals that carry out numerous X-rays each day and as such do not pose a significant exposure risk.
- Under the standard covering the irradiation of food in Australia and New Zealand, this energy can be in the form of Cobalt 60 sourced gamma rays, machine generated Xrays, or an electrically generated electron beam.
- Irradiation can kill harmful bacteria and other organisms in meat, poultry, and seafood, disinfest spices, extend shelf-life of fresh fruits and vegetables, and control sprouting of tubers and bulbs such as potatoes and onions.
- It is a safe process that has been approved by the U.S. Food and Drug Administration (FDA) and over 50 other national food control authorities for many types of foods

2.15 Radiation Sources

- Only certain radiation sources can be used in food irradiation. Energies from these radiation sources are too low to induce radioactivity in any material, including food.

These are :-

- Accelerated electron machines having a maximum energy of 10 MeV.
- Gamma rays using the radionuclides cobalt-60(used commonly) or cesium-137 (used very rarely);
- X-ray machines having a maximum energy of 5million electron volts (MeV); or

Accelerated electron beams (E-beams)

- The Electron Beam Linear Accelerator, (Ebeam) Accelerators work on the same principle as a television tube. Instead of being widely dispersed and hitting a phosphorescent screen at low energy levels, the electrons are concentrated and accelerated to 99% of the speed of light. This produces rapid reactions on the molecules within the product. The Electron Beam Linear Accelerator machine generates and accelerates electrons to energies of 5,7.5 or 10 MeV (Million electron volts) with beam power of up to 10 kW

- The electron beam is a stream of high energy electrons, propelled out of an electron gun.
- The electron gun apparatus is a larger version of a standard television tube.
- The electron beam generator can be simply switched on or off. There are no radioactive materials in the process.
- The electrons can penetrate food only to a depth of 3-5 cm, so the food to be treated must be no thicker than that to be treated all the way through. Two opposing beams can treat food that is twice as thick.
- E-beam medical sterilizers have been in use for at least 15 years

X-Rays

- X-rays are caused by atomic transitions and they are usually less energetic than gamma rays.
- X-rays with varying energies are generated by machines.
- The X-ray machine for food irradiation is a more powerful version of the machines used in many hospitals and dental offices to take X-ray pictures.
- To produce the X-rays, a beam of electrons is directed at a thin plate of gold or other metal, producing a stream of X-rays.
- Like E-beams, the machine can be switched on and off, and no radioactive substances are involved.

- Food-borne illnesses take a heavy toll on the economy and productivity of populations in most countries. In the US
- 76 million illnesses;
- 325,000 hospitalization;

- 5,000 deaths each year or approximately 100 deaths per week.
- Micro-organisms such as E. coli O157:H7, Campylobacter, Salmonella, Listeria, Vibrio and Toxoplasma are responsible for 1,50 deaths annually in the US.
- The most important public health benefit of food irradiation is its ability to destroy pathogenic (disease causing) organisms through pasteurisation.
- It is the only process that can do so effectively in raw and frozen foods.

2.16 Radiation sterilisation

- Sterilisation by irradiation can be applied to foods
- a relatively high dose of irradiation (above 10 kGy), together with a mild heat treatment and proper packaging, can kill all microorganisms and allow foods to be kept for long periods at room temperature.
- This process is analogous to canning, which uses heat treatment to achieve the same preservation status.
- Meat, poultry, some types of fish and shellfish, some vegetables and entire meals are suitable for radiation sterilization
- Radiation sterilization has been used in the U.S. to sterilize food for NASA's astronauts and for some patients with impaired immune systems.
- Radiation sterilization of food/meals could help outdoor enthusiasts (campers, mountain climbers, sailors, etc.) carry safe, nutritious and ready to eat food that requires no refrigerated storage.

2.17 Replacing chemical fumigation of food

- Irradiation can kill insects and microorganisms in cereals, legumes, spices and dried vegetable seasonings, as well as other stored foods.
- Irradiation could be used in place of chemical fumigation with ethylene dibromide (EDB, now banned in the U.S. and most other countries), ethylene oxide (banned in the European Union and Japan) and methyl bromide (MB).

2.18 Sprout inhibition

- Very-low-dose irradiation treatment inhibits the sprouting of vegetables such as potatoes, onions and garlic.

- Irradiation can replace the chemicals currently used for this purpose.
- The US and many other nations have approved this use of irradiation for several types of roots, tubers, and bulbs.
- Currently, irradiation is used extensively to control sprouting of garlic and potatoes in China and Japan, respectively

2.19 Enhancing food quality

- Low-dose irradiation also delays ripening and therefore extends the shelf-life of some fruits, including bananas, mangoes, papayas, guavas and tomatoes.
- Medium doses can be used to control mould growth on strawberries, raspberries and blueberries, thereby extending their shelflife.
- Cap opening of mushrooms can also be delayed by relatively low dose irradiation and cool storage.
- Irradiation can produce desirable physical changes in some foods.
- Bread made from irradiated wheat has greater loaf volume when certain dough formulations are used,
- Irradiated dehydrated vegetables reconstitute more quickly than non-irradiated vegetables, and
- When fruits such as grapes are irradiated they yield more juice than non-irradiated ones.

2.20 Eliminating parasite hazards in foods

- A low dose of radiation can eliminate the hazards of humans contracting trichinosis and toxoplasmosis from consumption of fresh foods such as pork without significantly affecting the flavour or texture of the meat.
- Irradiation treatment works by impairing the development of these parasites (Trichinellaspiralis , Toxoplasma gondii) so that they cannot mature, complete their life cycles or cause human diseases.

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – III – FOOD TECHNOLOGY – SCH1609

FOOD CANNING TECHNOLOGY

3.1Drying

Drying is one of the oldest techniques used to hamper the decomposition of food products. As early as 12,000 B.C., Middle Eastern and Oriental cultures were drying foods using the power of the sun. Vegetables and fruit are naturally dried by the sun and wind, but "still houses" were built in areas that did not have enough sunlight to dry things. A fire would be built inside the building to provide the heat to dry the various fruits, vegetables, and herbs.

3.2 Cooling

Cooling preserves foods by slowing down the growth and reproduction of micro-organisms and the action of enzymes that cause food to rot. The introduction of commercial and domestic refrigerators drastically improved the diets of many in the Western world by allowing foods such as fresh fruit, salads and dairy products to be stored safely for longer periods, particularly during warm weather.

3.3 Freezing

Freezing is also one of the most commonly used processes, both commercially and domestically, for preserving a very wide range of foods, including prepared foods that would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large-volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

3.4 Boiling

Boiling liquid food items can kill any existing microbes. Milk and water are often boiled to kill any harmful microbes that may be present in them.

3.5 Heating

Heating to temperatures which are sufficient to kill microorganisms inside the food is a method used with perpetual stews. Milk is also boiled before storing to kill many microorganisms.

3.6 Salting

Salting or curing draws moisture from the meat through a process of osmosis. Meat is cured with salt or sugar, or a combination of the two. Nitrates and nitrites are also often used to cure meat and contribute the characteristic pink color, as well as inhibition of Clostridium botulinum. It was a main method of preservation in medieval times and around the 1700s.

3.7 Sugaring

The earliest cultures have used sugar as a preservative, and it was commonplace to store fruit in honey. Similar to pickled foods, sugar cane was brought to Europe through the trade routes. In northern climates without sufficient sun to dry foods, preserves are made by heating the fruit with sugar. "Sugar tends to draw water from the microbes (plasmolysis). This process leaves the microbial cells dehydrated, thus killing them. In this way, the food will remain safe from microbial spoilage Sugar is used to preserve fruits, either in ananti-microbial syrup with fruit such as apples, pears, peaches, apricots and plums, or in crystallized form where the preserved material is cooked in sugar to the point of crystallization and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica and ginger. Also sugaring can be used in jam jellies.

3.8 Smoking

Smoking is used to lengthen the shelf life of perishable food items. This effect is achieved by exposing the food to smoke from burning plant materials such as wood. Smoke deposits a number of pyrolysis products onto the food, including the phenols syringol, guaiacol andcatechol.[6] These compounds aid in the drying and preservation of meats and other foods. Most commonly subjected to this method of food preservation are meats and fish that have undergone curing. Fruits and vegetables like paprika, cheeses, spices, and ingredients for making drinks such as malt and tea leaves are also smoked, but mainly for cooking or flavoring them. It is one of the oldest food preservation methods, which probably arose after the development of cooking with fire.

3.9 Pickling

Pickling is a method of preserving food in an edible anti-microbial liquid. Pickling can be broadly classified into two categories: chemical pickling and fermentation pickling.

In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other micro-organisms. Typical pickling agents include brine (high in salt), vinegar,alcohol, and vegetable oil, especially olive oil but also many other oils. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, corned beef, herring, and eggs, as well as mixed vegetables such as piccalilli.

In fermentation pickling, the food itself produces the preservation agent, typically by a process that produces lactic acid. Fermented pickles include sauerkraut, nukazuke, kimchi, surströmming, and curtido. Some pickled cucumbers are also fermented.

Lye

Sodium hydroxide (lye) makes food too alkaline for bacterial growth. Lye will saponify fats in the food, which will change its flavor and texture. Lutefisk uses lye in its preparation, as do some olive recipes. Modern recipes for century eggs also call for lye.

3.10 Canning

Canning involves cooking food, sealing it in sterile cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. It was invented by the French confectioner Nicolas Appert. By 1806, this process was used by the French Navy to preserve meat, fruit, vegetables, and even milk. Although Appert had discovered a new way of preservation, it wasn't understood until 1864 when Louis Pasteur found the relationship between microorganisms, food spoilage, and illness.[5]

Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives to can and only a short boiling cycle, whereas marginal vegetables such as carrotsrequire longer boiling and addition of other acidic elements. Low-acid foods, such as vegetables and meats, require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.

Lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (underprocessing) and poor hygiene allowing contamination of canned food by the obligate anaerobe Clostridium botulinum, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, however. Cooked mushrooms, handled poorly and then canned, can support the growth of Staphylococcus aureus, which produces a toxin that is not destroyed by canning or subsequent reheating.

3.10.1 Jellying

Food may be preserved by cooking in a material that solidifies to form a gel. Such materials include gelatin, agar, maize flour, and arrowroot flour. Some foods naturally form aprotein gel when cooked, such as eels and elvers, and sipunculid worms, which are a delicacy in Xiamen, in the Fujian province of the People's Republic of China. Jellied eels are a delicacy in the East End of London, where they are eaten with mashed potatoes. Potted meats in aspic (a gel made from gelatine and clarified meat broth) were a common way of serving meat off-cuts in the UK until the 1950s. Many jugged meats are also jellied.

A traditional British way of preserving meat (particularly shrimp) is by setting it in a pot and sealing it with a layer of fat. Also common is potted chicken liver; compare pâté.

3.10.2 Jugging

Meat can be preserved by jugging. Jugging is the process of stewing the meat (commonly game or fish) in a covered earthenware jug or casserole. The animal to be jugged is usually cut into pieces, placed into a tightly-sealed jug with brine or gravy, and stewed. Red wine and/or the animal's own blood is sometimes added to the cooking liquid. Jugging was a popular method of preserving meat up until the middle of the 20th century.

3.10.3 Burial

Burial of food can preserve it due to a variety of factors: lack of light, lack of oxygen, cool temperatures, pH level, or desiccants in the soil. Burial may be combined with other methods such as salting or fermentation. Most foods can be preserved in soil that is very dry and salty (thus a desiccant) such as sand, or soil that is frozen.

Many root vegetables are very resistant to spoilage and require no other preservation than storage in cool dark conditions, for example by burial in the ground, such as in astorage clamp. Century eggs are created by placing eggs in alkaline mud (or other alkaline substance), resulting in their "inorganic" fermentation through raised pH instead of spoiling. The fermentation preserves them and breaks down some of the complex, less flavorful proteins and fats into simpler, more flavorful ones. Cabbage was traditionally buried in the fall in northern farms in the U.S. for preservation. Some methods keep it crispy while other methods produce sauerkraut A similar process is used in the traditional production of kimchi. Sometimes meat is buried under conditions that cause preservation. If buried on hot coals or ashes, the heat can kill pathogens, the dry ash can desiccate, and the earth can block oxygen and further contamination. If buried where the earth is very cold, the earth acts like a refrigerator.

In Orissa, India, it is practical to store rice by burying it underground. This method helps to store for three to six months during the dry season.

3.11 Pickling

Pickling is the process of preserving or expanding the lifespan of food by either anaerobic fermentation in brine or immersion in vinegar. The resulting food is called a pickle, or, to prevent ambiguity, prefaced with the adjective pickled. The pickling procedure will typically affect the food's texture and flavor. In East Asia, vinaigrette (vegetable oil and vinegar) is also used as a pickling medium. Foods that are pickled includes: meats, fruits, vegetables, and most popular, pickles.

Another distinguishing characteristic is a pH 4.6 or lower, which is sufficient to kill most bacteria. Pickling can preserve perishable foods for months. Antimicrobial herbs and spices, such as mustard seed, garlic, cinnamon or cloves, are often added.[3] If the food contains sufficient moisture, a pickling brine may be produced simply by adding dry salt. For example, German sauerkraut and Korean kimchi are produced by salting the vegetables to draw out excess water. Natural fermentation at room temperature, by lactic acid bacteria, produces the required acidity. Other pickles are made by placing vegetables in vinegar. Unlike the canning process, pickling (which includes fermentation) does not require that the food be completely sterile before it is sealed. The acidity or salinity of the solution, the temperature of fermentation, and the exclusion of oxygen determine which microorganisms dominate, and determine the flavor of the end product.

When both salt concentration and temperature are low, Leuconostoc mesenteroides dominates, producing a mix of acids, alcohol, and aroma compounds. At higher temperatures Lactobacillus plantarum dominates, which produces primarily lactic acid. Many pickles start with Leuconostoc, and change to Lactobacillus with higher acidity.

Process

In chemical pickling, the jar and lid are first boiled in order to sterilize them. The fruits or vegetables to be pickled are then added to the jar along with brine, vinegar, or both, as well as spices, and are then allowed to ferment until the desired taste is obtained.

The food can be pre-soaked in brine before transferring to vinegar. This reduces the water content of the food which would otherwise dilute the vinegar. This method is particularly useful for fruit and vegetables with a high natural water content.

In commercial pickling, a preservative like sodium benzoate or EDTA may also be added to enhance shelf life. In fermentation pickling, the food itself produces the preservation agent, typically by a process involving Lactobacillus bacteria that produce lactic acid as the preservative agent.

Alum is used in pickling to promote crisp texture and approved as a food additive by the United States Food and Drug Administration.

"Refrigerator pickles" are unfermented pickles made by marinating fruit or vegetables in a seasoned vinegar solution. They must be stored under refrigeration or undergo canning to achieve long-term storage

Health benefits

Traditionally manufactured pickles are source of healthy probiotic microbes, which occur by natural fermentation in brine, but pickles produced using vinegar are not probiotic

Possible health hazards of pickled vegetables

The British Journal of Cancer released an online 2009 meta-analysis of research on pickles as increasing the risks of esophageal cancer. The report, citing limited data in a statistical meta analysis, indicates a potential two-fold increased risk of oesophageal cancer associated with Asian pickled vegetable consumption. Results from the research are described as having "high heterogeneity" and the study said that further well-designed prospective studies were warranted. Some common fungi can facilitate the formation of N-nitroso compounds, which are strong oesophageal carcinogens in several animal models. Roussin red methyl ester, a non-alkylating nitroso compound with tumour-promoting effect in vitro, was identified in pickles from Linxian in much higher concentrations than in samples from low-incidence areas. Fumonisin mycotoxins have been shown to cause liver and kidney tumours in rodents.

3.12 Salting

Salting is the preservation of food with dry edible salt. It is related to pickling (preparing food with brine, that is, salty water) and is one form of curing. It is one of the oldest methods of preserving food, and two historically significant salt-cured foods are salted fish (usually dried and salted cod or salted herring) and salt-cured meat (such as bacon). Vegetables such as runner beans and cabbage are also often preserved in this manner. Salting is used because most bacteria, fungi and other potentially pathogenic organisms cannot survive in a highly salty environment, due to the hypertonic nature of salt. Any living cell in such an environment will become dehydrated through osmosis and die or become temporarily inactivated. It was discovered in the 19th century that salt mixed with nitrites (saltpeter) would color meats red, rather than grey, and consumers at that time then strongly preferred the red-colored meat. The food hence preserved stays healthy and fresh for days avoiding bacterial decay.

3.13 Drying

Food drying is one of the oldest methods of preserving food. Since drying reduces the moisture in foods making them lightweight and convenient to store, it can easily be used in place of other food preservation techniques. In fact, one can even use drying along with other food preservation techniques such as freezing or canning, which would make the process of food preservation even better.

Drying food is simple, safe and easy to learn. The early American settlers practiced drying food using the natural forces of sun and wind and today, the use of technology has revolutionized this method of preserving food. With modern food dehydrators, foods such as fruit leathers, fruit chips, dried nuts and seeds and meat jerky, can all be dried year-round at home.

Being easy to store and carry and requiring no refrigeration makes dried foods ideal for domestic use as well as for use in the rough outdoors.

Moreover, dried foods are good sources of quick energy and wholesome nutrition, since the only thing lost during preservation is moisture. For instance, meat jerky, dried nuts and seeds are good sources of protein for a snack or a meal. The fruit leathers and chips provide plenty of quick energy. Dried vegetables, too, can be used to prepare wholesome casseroles and soups and the nutritional value can be enhanced by using the soaking water for cooking. Therefore, dried foods are an easy food option for busy executives, hungry backpackers and active women and children, all of whom can benefit from the ease of use and nutritional content of dried foods.

Drying basically dehydrates or removes the moisture from the food and this simple action inhibits the growth of bacteria, mold and yeast. Moreover, it slows down the enzyme action without deactivating them. These factors ensure that food does not spoil easily and hence, makes drying an effective food preservation technique.

Since drying removes the water from the food, the weight of the food item also reduces. This not only makes it lighter but also shrinks it in size. In order to use the food, all one has to do is add water to it.

The best temperature to dry foods and preserve them is 140 deg F. However, for meats and poultry, the USDA Meat and Poultry Hotline recommends heating meat to 160 deg F and poultry to 165 deg F before starting the drying process. Once the heating is done, the dehydrator temperature should be consistent at 130 to 140 deg F. Using temperatures higher than this will result in cooking the food instead of drying it. The food will cook on the outside and the moisture will remain trapped within. Drying is a slow process and one shouldn't try and speed it up by raising the temperature.

Another factor that helps with drying food is humidity. Since drying involves extracting the moisture from the food items and expelling it into the surrounding air, low humidity will help with the drying process. If the humidity is high, drying will be slower simply because the surrounding air would also be laden with moisture. By increasing the currents or flow of air, one can speed up the drying process.

There are several ways of drying foods – in the sun, in an oven or in a commercial dehydrator. However, in either case, it is important to have the right temperature, air flow and level of humidity.

Sun Drying

Drying food in the sun is a safe and economical way to preserve food, especially fruits. Meats and vegetables, however, cannot be dried outdoors since they have a low sugar and acid content. Fruits have a high sugar and acid content, which makes sun drying safe and easy. Meats and vegetables are best dried indoors in a controlled oven or dehydrator since temperature and humidity are essential when preserving these food groups.

In order to dry food in the sun, one needs to have both warm temperatures and a constant breeze. A minimum temperature of 85 deg F is essential while higher temperatures are obviously better. The high temperature will extract the moisture while the breeze would help to dispel it into the surrounding air. A low level of humidity is also essential for successful sun drying. The high humidity levels in the South make sun drying difficult. Humidity of below 60 percent is ideal.

Raisins dried in the sun are probably the most widely known of dried fruits. The sunny region of California produces a large portion of these raisins and the reason is simple. The temperatures in the San Joaquin valley are warm, the humidity is low and there is a constant breeze. These conditions are ideal for drying and preserving fruits, especially grapes.

Sun drying is a slow and time-consuming process since the unpredictable and uncontrollable weather is the drying agent. Moreover, it is this unpredictability, that also makes sun drying a risky process. For instance, in California, sudden rains can ruin the entire supply of raisins. Not only that, having the ideal mix of temperature, humidity and air flow is often difficult to achieve and this prompts one to look for other methods of drying food.

Fruit that is being dried in the sun needs to be protected from the cool night air that could add the moisture back to the fruit. Therefore, the fruits must either be brought in every night or put under some form of shelter to protect them from the night dew.

Equipment

For drying food in the sun, one needs racks or screens that are placed on blocks or on a concrete surface. This arrangement and equipment ensures adequate flow of air around the food. To prevent transfer of moisture from the earth, place the racks or screens on a concrete surface or over a sheet of aluminum, which will help to increase the temperature.

It is essential to use food-grade quality materials for the screens or racks. Ideally one should use screens made of stainless steel, Teflon-coated fiberglass or plastic. Avoid screens made of copper, aluminum or “hardware cloth” which is basically galvanized metal coated with zinc or cadmium. All these metals are unsafe since they can oxidize, leave residue on food or affect the nutritional quality of food items.

To protect the drying fruits from birds and insects, it is important to protect the fruits with some form of covering. To do this, one can simply use either another screen or a covering of cheesecloth.

Solar Drying

Solar drying is the result of technological advances made in the field of sun drying. Solar drying is a process of drying foods by harnessing the heat energy of the sun in a special dehydrator that not only increase the temperature but also, improves the air flow. This speeds up the process of drying the food and reduces the risk of food getting moldy or spoilt.

A solar dryer increases the temperature by using a reflector such as glass or aluminum while air flow is improved with the help of vents at each end. The technique and system is fairly simple. Cool air enters the dryer, removes moisture and escapes. The reflector surface helps to increase the heat by 20 deg F to 30 deg F. A cover of plastic protects the food, prevents rain or dew from dampening it and screens over the vents prevent birds and insects from attacking the fruit.

One may need to change the position of the solar dryer throughout the day in order to maximize the heat received from the sun. Also, one will have to stir the food several times to ensure uniform drying.

Solar dehydrators are available easily and in many variants. One can even make them at home after getting the requisite directions.

Vine Drying

Vine drying is yet another simple and effective way of drying food outdoors. This method is especially useful for beans and lentils. All one needs to do in order to dry beans such as kidney, soy, lima, navy and lentils, is to leave the bean pods on the vine till the beans inside rattle. It is relatively simple since no pretreatment of food is required. Once the bean pods are completely dry, simply pick them and shell. If required, further drying may be completed by drying them in the sun, oven or a commercial dehydrator.

3.14 Pasteurization

It is important to treat fruits and beans dried in the sun or on the vines and kill any insects and their eggs. One can use any one of these two methods for this purpose. The first is the freezer method. For this, one can simply seal the dried food in freezer plastic bags and place them in a freezer set at 0 deg F or below and leave them at least 48 hours.

The second is the oven method. For this place the food in a single layer on a tray or in a shallow pan, and then place the tray or pan in an oven preheated to 160 deg F for 30 minutes. “Pasteurization” is named after Pasteur, who demonstrated that wine spoiled because of the presence of microorganisms and that a mild heat treatment could be used to inactivate the microorganisms and thereby extend the shelf life. Pasteurization is most well known for its application to milk, which is strictly regulated through the U.S. Public Health Service/FDA's Pasteurized Milk Ordinance.

Pasteurization is most generally applied to liquids, although it is also applied to semisolid and solid foods. As applied to liquids, the temperature is elevated to 140 to 212°F for a short period of time (usually less than 1 min) to inactivate microorganisms that can cause illness (pathogens). As originally applied, the liquid was heated after it was put into the container; but by applying advances in food engineering, such as the understanding of flow dynamics and heat transfer to flowing liquids, continuous processes were developed using heat exchangers, machines used to transfer heat from a hot fluid to a colder one. Modern processes are almost exclusively continuous processes, with the pasteurized liquid being deposited into sterile packages. Most pasteurized foods are subsequently kept in refrigerated storage to extend the shelf life because not all spoilage organisms present have been inactivated.

3.15 Food Science

Drying, canning, chemical preservation, refrigeration (including chilling and freezing), and nutrient conservation and fortification were the significant advances of the 19th and 20th centuries and permitted population growth in more developed countries. Such population growth could only occur if there was sufficient food. The industrial revolution could not have occurred without a food delivery system that allowed people to leave the farms, migrate to the cities, and engage in useful production of goods and services for society.

Among the important developments during the early part of the 20th century were the discovery of vitamins and the realization of the importance of other micronutrients such as iodine, iron, and calcium. Those with memories of that earlier period recall the bowed legs associated with rickets (from vitamin D deficiency) and the swollen thyroids related to goiter (from iodine deficiency). With the introduction of the draft just before World War II, the army discovered widespread malnutrition among young American males. This led to the foundation of the Food and Nutrition Board of the Inst. of Medicine of the Natl. Academies and also the development in 1941 of the Recommended Dietary Allowances (RDAs) for essential nutrients. The difficulty of achieving these RDAs from available foods, especially among the poor, led manufacturers to fortify common foods with vitamins and other micronutrients, beginning with iodized salt in 1924. Today, fortified foods, defined by federal Standards of Identity, include such staples as pasta, milk, butter, salt, and flour.

Technological innovations in food preservation were dependent on advances in the sciences, especially chemistry and microbiology. How these sciences and technologies are applied within each society depends on the economic, biological, cultural, and political contexts for each society. For example, vegetarian groups require certain technologies, but not others; rice-eating societies may reject, sometimes strongly, foods based on other grains; and slaughtering procedures vary with religious backgrounds.

Advances in agriculture and food science and technology have led to reduction in nutrient deficiency-related diseases; a generally safe food supply with consistent high quality available independent of seasons; food choices that do not require preparation time; a wide range of delicious foods; reduced food waste; lower household food costs than ever before; convenience foods requiring much less preparation time than before, a benefit for working families; and efficient global food distribution that can be exploited in times of natural and man-made disasters.

Food is central to human health, not only in terms of quantity, but also quality as well. The past few decades have seen alarming rates of increase in chronic diseases such as diabetes, cardiovascular disease, and cancer, as well as autoimmune diseases such as inflammatory bowel disease and autism. A growing body of epidemiological, clinical, and basic research shows that food and diet are important factors involved in the etiology of these and other chronic diseases, and that dietary patterns have a profound effect on the risk for chronic diseases. Anand and others (2008), for example, describe the substantial role of environment lifestyle risk factors (such as sun exposure, diet, obesity, and physical inactivity) for cancer and provide evidence that cancer could be preventable for some people but that this would require major lifestyle changes. Hence, whether it is food safety and security, or nutrient deficiency and disease prevention, food is intricately connected to human health and well-being.

Dietary guidelines are produced to provide advice on good dietary habits that will promote health and reduce risk for major chronic diseases. The 2005Dietary Guidelines for Americansincludes recommendations to increase consumption of fruits, vegetables, whole grains, and low-fat milk, and to limit consumption of trans fats, saturated fats, cholesterol, and sodium. Many food companies have responded to these recommendations. For example, more bread and cereal products are now available that are made from whole grains and have higher fiber contents. The introduction of baby carrots doubled intake of carrots. Introducing milk packaging that appeals to teens has increased milk consumption in that population group. Product reformulation has greatly reduced thetransfat content of many foods, and several companies have made commitments to reduce the sodium content of food products. Convenient and innovative toddler foods made from a variety of fruits, vegetables, whole grains, and dairy are now available. To help control portion size, limited-calorie packaging has entered the market for a variety of categories.

Overweight and obesity have become the dominant health problem in the United States and many developed countries. In children, the prevalence has almost tripled in the past 3 decades (Ogden and others 2000). This is of particular concern because overweight children have a high likelihood of becoming overweight adults, with all the associated diseases such as metabolic syndrome and diabetes. Recent research suggests that childhood obesity is determined by age 2 (Harrington and others 2010), which supports the earlier set-point theory that body weight is regulated at a predetermined or preferred level by a feedback-control mechanism (Harris 1990). The obesity issue is a scientifically complex issue of behavior and may be economically driven; some of the lowest priced foods are the more calorie-dense and palatable products (Drewnowski 2004; MacAulay and Newsome 2004).

Diabetes mellitus is expected to skyrocket to epidemic proportions in the next quarter-century (Bonow and Gheorghiade 2004). Lifestyle interventions are the 1st step in the management of diabetes and metabolic syndrome (Stone 2008).

Even in the midst of an abundance of energy from food, however, many people do not meet their nutrient requirements, sometimes because of the types of foods available to them, other times because of the kinds of foods they select. The report of the 2010 Dietary Guidelines Advisory Committee (DGAC 2010) recommended focus on achieving energy balance through the current nutrition.

Food processing has evolved from merely a need to preserve foods from the time and location of harvest or assembly until the product reaches the consumer, to possibly complex activities that may include sourcing raw materials and ingredients from different parts of the world that can improve nutritional and other desirable qualities for better overall health and wellness of consumers. Food processing frequently serves multiple objectives. For example, freezing or cooking and freezing both preserve and provide convenience. Heating or fermentation of soy is necessary both to achieve edibility and to remove the hemagglutinens that would be mildly toxic. Processing operations are conducted under controlled conditions to ensure that the process is completed in the most effective and efficient manner. The resulting products include ingredients delivered to food manufacturers to be used in producing foods for consumers, as well as ingredients (for example, flour) for consumers to use in food preparation.

The development and implementation of new technologies enhances food quality and safety. New and innovative products, some with unique product attributes, have been developed through the use of new processing technologies.

The formulation, processing, and packaging of a food or beverage is accomplished for several clearly definable purposes, with numerous benefits to the consumer and society:

- Preservation. This is the oldest and perhaps still the most common purpose, and the one most familiar to consumers. The purpose of preservation is to extend the shelf life of a food or beverage.
- Safety. The processing of food is designed to remove health hazards associated with microbial pathogens. Processing operations dealing with raw food materials or ingredients carrying pathogens have significant controls and regulations to detect and inactivate food-borne microorganisms that can cause illness. Pasteurization of milk is just one of many examples of processes that eliminate a health hazard for the consumer and extend the life of the product.

Managing food safety, however, goes beyond microbiological risks. Good agricultural and manufacturing practices and other principles address chemical and physical hazards as well. In addition, plant breeding has contributed to reduction of some of the toxicants that occur naturally in foods in small amounts (ACS 1968; Hall 1977) and have been the source of common and sometimes widespread human illness and occasionally death. Processing is, however, still necessary in some instances. For example, manioc must be crushed and soaked—or crushed, heated, and treated with acid to remove hydrogen cyanide from cyanogenic glycosides before the resulting starch (tapioca) is safe to consume.

- Quality. Processes to ensure the delivery of foods and beverages of the highest quality to the consumer continue to evolve. Quality attributes include taste, aroma, texture, color, and nutrient content. In most cases, these attributes begin to decline as soon as a raw food material or ingredient is harvested or collected. The goal of the processes is to ensure that the decline in quality attributes is minimized. For example, blanching and freezing vegetables immediately after harvesting ensures that the nutrients remain at their peak level. In some cases, the quality attributes are enhanced by processing. For example, processing of soybeans greatly improves their flavor.
- Availability. Food processing helps to ensure that the consumer has access to a wide variety of foods and food ingredients at any time, including those that help to improve the retention of quality attributes for the period of time required for delivery of the product to the consumer. For example, controlling the composition of the atmosphere surrounding apples and other fruits leads to extended freshness.
- Sustainability. Food processing ensures that the resources required to produce raw food materials and ingredients for food manufacturing are used most efficiently. Responding to the goals of sustainability requires the maximum utilization of all raw materials produced and integration of activities throughout all the production-to-consumption stages. To maximize the conversion of raw materials into consumer products, efforts begin at the production stage, with activities to reduce postharvest losses and increase use of by-products. Efforts continue, through food manufacturing and beyond, to ensure that energy, water, and other resources are used most efficiently and environmental impacts are minimized. Refrigeration of fresh produce is an example of an action that reduces loss and increases the edible life of the product.
- Convenience. Many processed foods and beverages are developed to allow them to be consumed after limited amounts of preparation. For example, a frozen or refrigerated entree is delivered to the consumer in a form ready for microwave heating. Snack foods are ready to eat when delivered to the consumer.
- Health and Wellness. At a fundamental level, food is viewed as a source of nutrition to meet at least the minimum daily requirements for survival, but there is an ever-greater focus on the desire for health optimization from food. Processing can enhance the nutritional value of foods in a number of ways. For example, refining—separation of the antinutritional components—is the best means of

improving the nutritional quality of many foodstuffs of vegetable origin, and processing of fresh tomatoes (for example, into catsup) improves the bioavailability of the carotenoid lycopene.

Some products are specifically designed to enhance individual health and wellness—the focus of many current trends—requiring specific unique ingredients and an array of processes to ensure desired product attributes. Many products are fortified or enriched with vitamins and minerals (for example, orange juice fortified with calcium for bone health) and other nutrients (for example, margarine enriched with plant stanols and sterols for heart health) in response to defined nutritional needs of consumers. The success of these products—often referred to as "functional foods"—requires that flavor and texture also meet consumer expectations.

The mechanical operations, processes, and technologies typically used to achieve these benefits in preparing and using raw materials in manufacturing foods and beverages (Potter and Hotchkiss 1995) are briefly described below:

Mechanical Operations. There are many mechanical operations used throughout the food system, including simple conveying of raw materials from one location to another, as well as more intense operations to change the physical structure of the material. All or most of these operations are larger scale versions of operations that have been used to prepare foods for centuries. The cracking and grinding of cereal grains to manufacture the flour used in bakery products is a very visible example. Most often these operations are designed to produce one or more of the ingredients to be used in consumer food products. The extraction of oil from soybeans and other oilseeds requires a mechanical operation before efficient separation of the oil can be accomplished. In most cases, these operations are a component of series of steps needed to ensure the most efficient use of the raw material, often including the manufacturing of an array of by-products for consumers to utilize. Another typical mechanical operation is dry mixing, involving the blending of various ingredients to ensure homogeneous and uniform distribution of the various ingredients before a final stage of manufacturing.

• Heating. The use of thermal energy to increase the temperature of a raw food or ingredient is the most recognized and widely used approach to preservation of food. By increasing the temperature to appropriate levels and holding for an appropriate time that is dependent on both the nature of the food and the objective of the process, pathogenic or spoilage microorganisms are significantly decreased in number or eliminated.

Thermal processes applied to foods in food manufacturing are based on the same principles as those governing traditional cooking of foods during preparation. The impact of heating—thermal processing—on components of the food is the same as that during cooking and often results in the enhancement of flavors and texture, as well as some modest losses of heat-sensitive nutrients. Many shelf-stable foods are available to consumers as a result of thermal processing. Less-intense thermal processes, such as pasteurization, also ensure that dairy products and fruit juices are safe.

Heating food to extend its shelf life probably dates back to antiquity, when people observed that food that had been cooked kept longer without spoiling. However, it was not until Appert and others investigated heating foods in containers that it was discovered that immediate recontamination of heated food from the environment did not occur. Since those meager beginnings, advances in mathematics, chemistry, biology, and engineering, coupled with their application to food science and technology, have resulted in development of equipment and procedures to optimize the application of heat to foods for the purpose of extending their shelf life and enhancing their edibility (texture, flavor, and visual appearance).

There are basically 3 types of heat processes that are applied to food, other than cooking: blanching, pasteurization, and canning. The latter 2 are tightly regulated by federal—and in some cases, state—agencies to ensure proper application of the technology and prevention of food-borne illness.

Blanching is a mild heat treatment (usually accomplished at temperatures below 212°F for less than 2 to 3 min) applied to foods that are to be subsequently canned, frozen, or dried. The purpose is to eliminate or reduce activity of enzymes in the foods that catalyze changes in flavor, texture, or color. Other benefits include removal of air from the food tissue to reduce oxidation, softening of the plant tissue to facilitate packing into packages, and inactivation of antinutritional properties (such as trypsin inhibitor in soybeans, a naturally occurring chemical that reduces dietary protein breakdown in the human gastrointestinal tract).

The process is usually carried out in hot water or steam, although there are processes based on hot air or microwave heating. Since the process is relatively mild, there is relatively little effect on nutrients, although when hot water is used as the heating medium some nutrients, especially water-soluble nutrients, are leached into the water.

“Canning” is primarily used to inactivate microorganisms that cause food-borne disease such as botulism, but it also inactivates microorganisms that cause food spoilage. This thermal process is commonly accomplished by holding the product at temperatures well above 230°F for several minutes. Canned food is not absolutely sterile (devoid of all viable microorganisms) but rather is commercially sterile (devoid of all viable microorganisms that could grow under normal storage conditions).

There are 2 major methods: heating the food after it has been sealed in a container (referred to as canning) and sterilizing the food, then depositing it in a sterile container within a sterile environment and sealing the container (referred to asaseptic processing). These processes can also be optimized for retention of nutrients and quality factors such as taste, flavor, and color. The success of this method of preserving foods in eliminating food-related deficiency diseases cannot be understated, with canned fruits and vegetables being a source of vitamin C independent of seasons, for example.

- Refrigeration and Freezing. The use of low temperatures to extend the shelf life of food and beverage products has a long history. The use of ice to reduce the temperature of foods and prevent spoilage has been recognized for centuries. Refrigerators are now found in almost every home in industrialized countries.

Although the reduction of temperature does not eliminate microbial populations, it reduces the rate of microbial growth enough to prevent product spoilage and extend the shelf life of most food products. Most fruits and vegetables are refrigerated to extend their freshness. In addition, refrigeration also reduces the reaction rates of enzymes that cause deterioration of most quality attributes of a food or beverage, making high-quality products available to the consumer for extended periods of time (Heldman and Hartel 1997).

Some foods and beverages receive a mild heat treatment to inactivate enzymes and eliminate microorganisms that can cause disease but still require refrigeration to control the growth of surviving microorganisms that can cause spoilage. Pasteurized milk is probably the best example, but many other foods and beverages are also pasteurized and then refrigerated. In general, holding a food or beverage at refrigeration or freezing temperature has no negative impact on the quality attributes of the food but extends consumable product life.

“Freezing” is a more intense use of refrigeration to reduce the temperature of a product to levels below the freezing temperature of water in the product. Lower temperatures cause the liquid water to change phase to ice. At these reduced temperatures (−0.4 to −14°F), the deterioration rates for product quality attributes are reduced to below those at refrigeration temperature, and microbial growth is reduced to negligible levels.

It is not unusual for frozen fruits, vegetables, and some meat products to maintain high quality for as much as 1 y while frozen. Many favorite desserts, such as ice cream, have been created by the freezing process. Most nutrients are not affected by freezing; however, it is difficult to freeze a food product without impact on the some of its more evident quality attributes. The formation of ice crystals within the structure of a plant or animal food results in a series of reactions with potential impact on texture and flavor. Thus, careful control of the time to freeze the product and the temperature of the frozen product during distribution and storage is important to minimize such reactions and ensure the best possible quality attributes over time (Erickson and Hung 1997).

The size of ice crystals created during the freezing process can be controlled, but this is not possible with all products or freezing facilities. For example, small pieces of fruits or vegetables can be frozen very rapidly, and the product structure is preserved with uniform distribution of small ice crystals. In contrast, a large portion of beef or any product in a large package will require a longer time to freeze and will result in a less-uniform distribution of larger ice crystals. The extent of the impact on product quality depends on an array of factors occurring after freezing, including control of temperature during storage and distribution and final preparation of the food. For many foods, the quality attributes of refrigerated and frozen foods compare favorably to those of the fresh counterparts (Mallet 1993).

• Dehydration. Drying is intended to halt or slow the growth of microorganisms and rate of chemical reactions. The removal of water provides food processors excellent opportunities to reduce volume and weight, extend shelf life, and convert liquids to powdery products, such as instant coffee or a vegetable soup base mix. This process is one of the oldest techniques used to preserve foods, one of the most utilized, and the most energy intensive (von Loesecke 1943; Saravacos 1965; King 1968; Thijssen 1979).

Water removal is usually performed via evaporation, vaporization, or sublimation (drying while frozen) by means of a simultaneous heat, mass, and momentum transfer mechanism (Whitaker 1977). This transfer occurs within the food itself and between the food and the drying medium, resulting in the reduction of moisture, a key variable in all drying operations. In addition to water removal, chemical reactions occur, such as Maillard browning (nonenzymatic browning) of amino acids/reducing sugars such as glucose, caramelization of sugar, denaturation/degradation of cross-linking proteins, and pyrolysis (decomposition or transformation of a compound caused by heat) of the various organic constituents. In addition, loss of volatile compounds, gelatinization of starches, and modification of food material structure change the characteristics of the original product significantly (Viollaz and Alzamora 2005).

Many types of dryers, dehydration methods, and associated equipment are applied to a very wide range of foods. Sun drying on trays, mats, or platforms is the traditional method and is still used today. Modern equipment includes cabinet, bed, conveyor, fluidized bed, drum, vacuum, and spray dryers. Freeze drying (lyophilization), osmotic dehydration, microwave, and innovative light-driven refractance-window dryers are also in use. With continuous technological advances in different fields, drying is constantly evolving to offer better quality and novel products.

Mathematical modeling and process simulation have significantly contributed to the understanding of the intricacies of this very complex process and the design of new dryers and drying systems. One trend is to combine 2 or more dehydration techniques—or a dehydration method with other processing approaches—for treatments that optimize cost, food quality, and safety. Examples of these combinations include microwave–vacuum drying, ultrasound-assisted air drying, and encapsulation and flavor impregnation to add value.

• Acidification. Raw foods and beverages vary significantly in levels of acid they contain. Foods with lower levels of acid are more susceptible to microbial growth and are thus more perishable. The intentional adjustment in the level of acid in a food has been a preservation method for centuries, in making pickles, for example. This approach to preservation is based on the inability of many spoilage microorganisms and pathogens to grow at high levels of acid. Increasing the acidity prevents growth of many microorganisms and extends the shelf life of the product, while maintaining many of its attributes. This preservation method can be accomplished by addition of acid to adjust the overall acidity level of the product, or biologically through fermentation. Since acid alone may not be sufficient to fully protect the product, adjustments in acidity are frequently used in combination with other techniques such as heat, additives, or refrigeration to accomplish preservation and safety.

• Fermentation. The use of microorganisms to change a perishable food into a less-perishable product is another very old way of preservation that has been used around the world by societies without access to refrigeration to extend the edible life of a fresh food. Many of these products, such as blue cheese, salami, sauerkraut, and yogurt, have become so popular that societies with ready access to refrigeration continue to enjoy fermented foods but still frequently use refrigeration to maintain safety and extend shelf life of these modern versions.

Although some microorganisms lead to food spoilage and others cause food poisoning, specific microorganisms that can induce desirable changes in foods are used to overpower those that can lead to unappealing or unsafe foods. Fermentation microorganisms primarily work to change the chemical makeup of a product, making it less likely that undesirable microorganisms will reproduce and compromise product safety or quality. Beneficial microorganisms synthesize natural preservatives, such as lactic acid and other acids (increasing the acidity of the food), carbon dioxide (lowering the oxygen content), and ethanol (discouraging growth of undesirable microorganisms). Yeasts produce carbon dioxide to expand the structure, such as dough for bread baking. They are also responsible for the production of ethanol to produce beer, wine, and other alcoholic beverages.

Fermented dairy products include yogurt and a host of ripened cheeses. Fermented cucumbers are called pickles in Western countries, but pickling is another word for fermenting and is used to produce pickled eggs, pig's feet, and even snakes in certain countries. Many countries and cultures have their own favorite types of fermented products, such as injera from Ethiopia, kimchi (fermented cabbage) from Korea, salami and other fermented sausages from Italy and Germany, and sauerkraut from northern Europe. Harvested cacao beans are fermented before cleaning and roasting, making all chocolate products the result of at least one fermentation step.

• Water Activity. A very important and useful tool in the control of food quality attributes and food safety is water activity (aW). Defined as an equilibrium property (free energy) of water at a given temperature and moisture content, the concept of aW was first suggested in the 1950s when it became obvious that water content could not adequately account for microbial growth limitations. During the 1960s, researchers demonstrated that aW is also important in controlling the rates of chemical deterioration in foods, and then in the 1980s it was also found to relate to the texture of crisp dry foods and caking of powders such as instant coffee. aW is not the same as water content, or the quantitative amount of water in a sample, nor is it a measure of free compared with bound water in a food, an early misconception that is now abandoned.

Through the research of hundreds of food scientists, a number of aW paradigms have been established and used by food manufacturers to create safe, tasty, and nutritious dry and semimoist foods such as crispy snacks and breakfast cereals, semimoist cookies, and creamy confections. For example, it is known that at aW values between about 0.3 and 0.65, changes in product texture occur (for example, loss of crispness and onset of stickiness, caking, or hardening), and that at aW values around 0.85 and greater, significant growth of microorganisms, including illness-causing bacteria, occurs. In fact, the concept of aW is used in regulation of food processing to ensure food safety. TheCode of Federal Regulations(21 CFR 110.80 [b][14]) requires that "Foods such as but not limited to dry mixes, nuts, intermediate moisture foods, and dehydrated foods that rely on the control of aW for preventing the growth of microorganisms shall be processed to and maintained at a safe moisture level. Compliance … may be accomplished by any effective means including (i) monitoring the aW of ingredients and finished product, (ii) controlling the soluble solids-water ratio, (iii) protecting finished foods from moisture pickup … so that the aW does not increase to an unsafe level … ." In addition, aW is the key to control of enzyme activity, lipid oxidation, and many other reactions that have an impact on food quality, such as degradation of vitamins and changes in color, flavor, and aroma.

Preservation. Smoke functions as an antioxidant or flavor protector. Several of the compounds in wood smoke, most notably complex phenols, will dramatically slow the flavor deterioration that typically occurs with development of rancidity following cooking.

Despite the advantages, 3 criticisms have occasionally been leveled at the use of smoke for food preservation. First is that atmospheric emissions result from combustion of wood to generate smoke. Second is that it degrades some food nutrients; this has been demonstrated to be of very minor importance—smoke has been shown to not significantly alter the nutrient value of food under normal circumstances. Third is that combustion of wood can generate undesirable compounds (polycyclic hydrocarbons) shown to be toxic and/or carcinogenic.

Of note is that this process results in smoke deposition almost exclusively on the surface of the product, with relatively little penetration below the surface—smoke deposition is limited to the outer

¼ to ½ inch of the product. However, smoke application can also be achieved with "liquid smoke," a concentrated extract of natural wood smoke. Liquid smoke contains all of the important functional components of natural smoke and results in the same effects on color, flavor, and bacterial control, but it is much more consistent in composition than natural smoke and therefore more reproducible in effect.

Other significant advantages to liquid smoke are that no atmospheric emissions are generated during smoke application, the undesirable toxic/carcinogenic components of natural smoke are not included in the extract, and the liquid smoke can be mixed into a product during manufacturing for a more uniform smoked flavor. Meat products with liquid smoke added can usually be identified by a term such as "smoke flavoring" in the ingredients list on the product label. Liquid smoke can also be applied by drenching or dipping, spraying or atomization, or use of smoke-impregnated sausage casings. These application methods result in surface deposition of smoke components with product effects that are very similar to those produced by the surface application of natural smoke.

• Irradiation. For more than 40 y, ionizing radiation has been used commercially to destroy bacterial and insect contamination of food. Common sources of ionizing radiation today are electron beams, X-rays, and, more often, gamma rays (with the radioactive isotope cobalt-60, the same source used for radiation therapy in hospitals). Elaborate physical safeguards assure worker safety.

Irradiation is particularly effective in reducing microbial contamination of hamburger meat and poultry, which can be contaminated by pathogens such as Escherichia coli O157:H7, Salmonella , and Campylobacter and result in food-borne illness. Irradiation also may be applied to eliminate insects in a wide variety of foods, for example, flour, spices, fruits, vegetables, and grains (IFT 2004), to prevent seeds from sprouting, and to control pathogens in fresh shell eggs, seeds for sprouting, fresh or frozen molluscan shellfish (for example, oysters, clams, mussels, and scallops), and fresh iceberg lettuce and fresh spinach (Morehouse and Komolprasert 2004, FDA 2008). Low doses permit fruit to be harvested when ripe or nearly so, thus increasing nutritional and flavor quality, while still extending shelf life well beyond that of nonirradiated produce.

Irradiation works by damaging the DNA of living organisms; the targets are typically bacteria and insects, but the DNA of the plant or animal food is of course also affected. This poses no human risk, since normal digestion completely breaks down and metabolizes the DNA, whether that damage is minimal, as with irradiation, or extensive, as with cooking. Low doses of irradiation can achieve sprout inhibition and insect de-infestation; medium doses are required for reduction of spoilage and pathogenic bacteria; and high doses are required for sterilization. Irradiated foods must be labeled as such (21 CFR 179.26[c]). Irradiation is also used at high doses and in far higher volume to sterilize joint implants, bandages, sutures, drugs, cosmetics, and wine and bottle corks (Crawford and Ruff 1996; UW Food Irradiation Education Group 2010).

The effects of irradiation on nutritional quality vary depending on nutrient, food, and irradiation conditions (for example, dosage, temperature, and atmospheric conditions). Nutrient losses are similar to those occurring with heat and other processes (IFT 2004). Thiamin (vitamin B1) is sensitive to irradiation, but loss can be minimized with packaging techniques (Thayer 1990; Fox and others 1995, 1997).

Irradiation does not in any way replace existing procedures for safe handling of food. Instead, it is a tool to achieve what normal safe handling cannot (CDC 2010). Irradiation cannot make food safe that is already spoiled (UW Food Irradiation Education Group 2010).

Because of the usefulness of irradiation in dealing with microbial risks, the Centers for Disease Control and Prevention and other public health authorities have endorsed its use (CDC 2010). The same conclusions on safety and effectiveness have been reached by international agencies (WHO 1997; Morehouse and Komolprasert 2004). Codex Alimentarius, the international food standard-setting agency, has published aGeneral Standard for Irradiated Foods(CAC 2003a) and a Recommended International Code of Practice(CAC 2003b). Although regulations of irradiation of food vary from country to country, regulations in several countries have been or are being harmonized through compliance with the Codex General Standard(Morehouse and Komolprasert 2004). In the United States, food irradiation is regulated as a food additive, because in the Food Additives Amendment of the Federal Food, Drug, and Cosmetic Act of 1958 Congress defined radiation sources as food additives.

The safety of irradiated food, which has been tested extensively, has been clearly demonstrated (Diehl 1995; Crawford and Ruff 1996; WHO 1997; Morehouse and Komolprasert 2004; CDC 2010). Foods made sterile by irradiation to inactivate bacterial spores (at the highest doses) have been fed for years to patients with reduced immunity and to astronauts (CDC 2010; UW Food Irradiation Education Group 2010). Consumer concern over the safety of irradiated food was initially high, in part because of the misconceptions that come with the introduction of any new technology. Arguments against irradiation are similar to those voiced against pasteurization of milk, when it was introduced 100 y ago (UW Food Irradiation Education Group 2010). Concern still exists but has gradually declined as information on irradiation and its advantages have become more widely known (Conley 1992; Bruhn 1995; Morehouse and Komolprasert 2004; IFIC 2009).

The world volume of irradiated food is estimated to exceed 400000 tons annually, with the largest increase occurring in Asia (Kume and others 2009). The food industry has been slow to adopt food irradiation in the more developed nations because of the large capital investment required; there is little incentive to invest in irradiation equipment because of funds already allocated for refrigeration, canning, and other major processes. The situation is very different in developing areas, where existing processes are much less extensive and postharvest losses and the risks of food-borne illness are far greater. Some argue that this is where the need for irradiation is greatest and the ability to afford it is the lowest. In the United States, irradiation could reduceE. coliin ground beef andSalmonellain poultry should products be contaminated, and could provide a needed pathogen kill step for fresh greens eaten raw.

• Extrusion. This process pushes a material through a specially engineered opening to give a desired shape and texture through increases in temperature, pressure, and shear forces. The pushing force is applied by using either a piston or a screw. In food applications, screw extrusion is predominant. Examples of traditional extruded foods are pasta, noodles, vermicelli, and breakfast cereals. Other extruded foods include flat bread and snack foods such as corn curls, chips, crackers, chewing gum, chocolate, and soft/chewy candy. Extrusion is also used to create flavors and encapsulate them for heat stability in processing. Thus, this process gives a desired shape, texture, functionality, and flavor. Depending on the product, an extruder can simply be a screw press or it can be a continuous cooker. In the case of a screw press, the product is usually further processed extensively, such as by frying, baking, flaking, coating, or drying, as in the extrusion process to produce cornflakes. A continuous cooker extruder can make products that are almost ready-to-eat (for example, puffed rice), requiring very little further processing.

Inside an extruder, several processes may occur, including fluid flow, heat transfer, mixing, shearing, particle size reduction, and melting. In pasta manufacturing, for example, the main objective of the extrusion process is to partially gelatinize starch, compact the dough, and give it the desired shape. In the case of chocolate manufacturing, however, the extruder is used as a reactor to generate key flavor attributes. And, in the case of flat bread, an extruder is used to develop the desired expanded and porous structure.

Food extrusion is generally considered a high-temperature, short-time (HTST) process. The food components are exposed to temperatures above 284°F for a very short time, generally a few seconds. This gives a distinct advantage over conventional pressure cooking, in which the exposure could be several minutes at temperatures near 212 to 248°F.

Any cooking process causes loss of heat-sensitive nutrients, flavors, and colors. A combination of higher temperature and shorter time is desirable because it retains nutrients better than a combination of lower temperature and longer time. It has been found that vitamins A, C, E, B1, and folic acid are very sensitive to extrusion, whereas the B-complex vitamins B2, B6, B12, niacin, calcium pantothenate, and biotin are stable during extrusion.

Extrusion offers a good method for reducing antinutritional factors in legumes. For example, in peas, extrusion has been found to be more effective than germination for reducing tannins, polyphenols, and trypsin inhibitors. Extruders have been used as bioreactors for pretreatment of cereal grains for subsequent ethanol fermentation, enzymatic conversion of starch to glucose and maltose, and sterilization of ground spices such as black pepper, white pepper, and paprika. Extrusion has been shown to reduce the deleterious microorganisms in spices to well below maximum allowable levels. Extrusion is an environmentally friendly process that uses heat and power efficiently and does not produce effluents. In addition, the same equipment can be used to make a variety of products. Extruded products are safe to consume, with no known harmful effects.

• Modified/Controlled Atmosphere. The shelf life of many fresh foods has been extended by controlling the composition of the gas environment in direct contact with the product. For products with shelf life limited by chemical or enzymatic reactions involving oxygen, reducing or eliminating the oxygen content of the environment provides significant extension of the product shelf life (Floros 1990).

The shelf life of fresh fruits and vegetables is extended by controlling both the oxygen and carbon dioxide composition of the atmosphere surrounding the products, which are still actively undergoing respiration and continue to convert oxygen to carbon dioxide. Large-scale controlled-atmosphere storage of fruits and vegetables has become a standard approach to maintaining the highest product quality between the time of harvest and delivery to the consumer. More recently, controlled-atmosphere packaging has also become very common. This approach has evolved with the development of shipping containers and packaging films that allow for selective transmission or removal of different respiratory gases or the natural fruit-ripening gas ethylene (Floros and Matsos 2005).

The modification of product atmosphere must be approached with caution, because of the response of certain microbial populations. The most serious concerns are with anaerobic pathogens, such as Clostridium botulinum, that have the potential to grow and produce toxins in an oxygen-free environment. Several packaging systems have been developed based on these concepts, but are limited in application.

• Additives. Food additives are adjuncts to food processing. They extend the range and flexibility of the relatively few food processes available, and they improve the economics of the processes. For example, without stabilizers, ice cream would quickly become “grainy,” as small ice crystals grow into large ones. Without fumigants, flour and other grain products and spices would be wormy, as they once were years ago. Without fortification of milk and flour and the addition of iodine (in the form of iodate) to salt, rickets and goiter would still occur. Without artificial colors, many foods, such as gelatin, would be unattractive because natural colors lack the stability and coloring power of the synthetics. Without non nutritive sweeteners, a great many sweetened beverages, desserts, and confections would have unacceptable calorie contents or contain levels of sugar that cannot be consumed by certain individuals, such as people with diabetes and many others. Anticaking agents, enzymes, preservatives, emulsifiers (which allow immiscible liquids such as oil and water to form a stable mixture), humectants (which affect moisture retention through their affinity to water and stabilizing action on water content), and many other additives add significantly to the safety, nutritive value, attractiveness, convenience, and economy of our modern food supply.

The practical definition of a food additive—not the far longer, involved legal definition—is “Any substance added to food in small amounts to achieve a particular technical effect.” TheCode of Federal Regulations(21.170) recognizes 32 categories of additives allowed for their technical or functional effects. Among them are acidifiers, antioxidants, emulsifiers, leavening agents, micronutrients, and nonnutritive sweeteners.

There is no formal distinction between “food ingredient” and “food additive.” Common usage would suggest that an ingredient used at less than perhaps 1% of a food would be an “additive.” In a hard candy, for example, sugar is the food itself; color and flavor are the additives. In a lightly sweetened beverage, however, sugar could be an “additive.” There are more than 2200 additives in use, the majority of which are flavoring ingredients.

3.16 Packaging

Many different types of food packages are used for several different reasons. Food is packaged primarily to contain the product, protect the product from contamination, enable convenience, and provide information (Paine 1991; Robertson 1993; Yam and others 2005; IFT 2008).

Most food products are delivered to the consumer in some type of package. Foods that have received some type of preservation process are placed in a package to ensure that the product attributes enhanced by the process are maintained. Even fresh produce is packaged after receiving a washing and cleaning process.

Packaging offers a critical component of food safety by preventing contamination from pathogens. In addition, packaging extends the shelf life of the product by providing a physical barrier to or protection from atmospheric oxygen and moisture, light, and other agents that would accelerate deterioration of the product. Finally, packaging is the vehicle by which legally required information is presented to the consumer in the form of the label bearing information about the product identity, quantity, ingredients, nutrient content, expiration date, and commercial source.

Packaging has advanced from glass bottles, paperboard cartons, tin-plated soldered side-seam steel cans, and aluminum foil to 2-piece aluminum cans with “pop tops;” plastic, flexible, rigid, semirigid, and multilayer containers; microwave safe packages; and active and intelligent packaging (Floros and others 1997, 1998; Suppakul and others 2003; Ozdemir and Floros 2004; Yam and others 2005; Han and Floros 2007; IFT 2008). Innovations were driven by a number of forces, including convenience, consumer desire for minimally processed foods, changes in retail and distribution practices; foodservice needs; trend toward more sustainable packaging; and demands for global and fast transport of food (Suppakul and others 2003; IFT 2008).

Aseptic packaging is a major area of food packaging that has significantly increased the safety, quality, availability, and convenience of certain foods around the world, while reducing the amount of energy needed to preserve and store such foods. The major difference between aseptic packaging and traditional methods of food packaging is that in aseptic packaging the product and the packaging material are continuously sterilized separately. Then, under aseptic conditions that prevent recontamination of the product, the sterile package is filled with the cooled sterile product and hermetically sealed to produce a shelf-stable final product with extended shelf life and no need for refrigerated storage. This technique has allowed for substantial improvements in the quality of the final product, mainly due to the much milder heat treatment that the product undergoes compared to the traditional thermal process (Floros 1993). Large-scale aseptic bulk processing and packaging, combined with aseptic storage and transportation, contributes significantly to reduction of postharvest fruit and vegetable losses and greater availability of these food products around the world. Many advances in the packaging of food took place in the past 20 to 30 y, producing a wide variety of new materials and processing technologies. The steady accumulation of research developments indicates that food packaging will continue to evolve and respond to the changing needs of the food system and the increased demands of consumers.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – IV – FOOD TECHNOLOGY – SCH1609

FOOD PRESERVATION METHODS

A well designed process ought to be easy to control. More importantly, it is best to consider the controllability of a process at the very outset, rather than attempt to design a control system after the process plant has been developed

4.1 Objectives of control

- Process control is an integral part of modern processing industries; and the food processing industry is no exception.
- Process control is to improve the economics of the process by achieving the following objectives
- To reduce variation in the product
- To quality, achieve more consistent production and maximize yield,
- To ensure process and product safety,
- To reduce manpower and enhance operator productivity,
- To reduce waste and
- To optimize energy efficiency

4.2 Mode of operation

Processes are operated under either

- steady state, i.e. process conditions do not change, or unsteady state conditions, process conditions depend on time.

The latter occurs in most real situations and requires control action in order to keep the product within specifications.

4.3 Two basic steps of any control action

- Accurate measurement of process parameters;
- Manipulation of one or more process parameters using control systems in order to alter or correct the process behavior.

4.4 Measurement of Process Parameter

- Accurate measurement of the process parameters is absolutely critical for controlling any process.
- Three main classes of sensors used for the measurement of key processing parameters such as temperature, pressure, mass, material level in containers, flow rate , density, viscosity, moisture, fat content, protein content, pH, size, color, turbidity etc.
- Penetrating sensors: these sensors penetrate inside the processing equipment and come into contact with the material being processed.
- Sampling sensors: these sensors operate on samples which are continuously withdrawn from the processing equipment.
- No penetrating sensors: these sensors do not penetrate into the processing equipment and, as a consequence, do not come into contact with the materials being processed.

4.5 Characterization of sensors according to their applications

- Inline sensors: these form an integral part of the processing equipment, and the values measured by them are used directly for process control.
- Online sensors: these too form an integral part of the processing equipment, but the measured values can only be used for process control after an operator has entered these values into the control system.
- Offline sensors: these sensors are not part of the processing equipment, nor can the measured values be used directly for process control. An operator has to measure the variable and enter the values into a control system to achieve process control.

4.6 Characteristics to be evaluated before using a sensor

- Response time, gain, sensitivity, ease and speed of calibration,
- Accuracy, stability and reliability,
- Material of construction and robustness and
- Availability, purchase cost and ease of maintenance.

4.7 Types of control systems

Control systems can be of two types:

- Manual control and
- Automatic control.

4.7.1 Manual Control

- an operator periodically reads the process parameter which requires to be controlled and, when its value changes from the set value, initiates the control action necessary to drive the parameter towards the set value.

4.7.2 Automatic Control

- The process parameters measured by various sensors and instrumentation may be controlled by using control loops. A typical control loop consists of three basic components
- Sensor: the sensor senses or measures process parameters and generates a measurement signal acceptable to the controller.
- Controller: the controller compares the measurement signal with the set value and produces a control signal to counteract any difference between the two signals.
- Final control element: the final control element receives the control signal produced by the controller and adjusts or alters the process by bringing the measured process property to return to the set point, e.g. liquid flow can be controlled by changing the valve setting or the pump speed.

4.8 Classification of an automatic control system

An automatic control system can be classified into four main types:

- on/off (two position) controller
- proportional controller (P-controller)
- proportional integral controller (PI controller)
- proportional integral derivative controller (PID controller).

4.8.1 On/Off (Two Position) Controller

- the simplest automatic controller for which the final control element, e.g. valve, is either completely open or at maximum, or completely closed or at minimum.
- There are no intermediate values or positions for the final control element.
- FCE,s often experience significant wear, as they are continually and rapidly switched from open to closed positions and back again.
- on/off controllers are provided with a dead band.
- dead band is a zone bounded by an upper and a lower set point.
- On/off controllers with a dead band are found in many instances in our daily lives: home heating system, oven, refrigerator and air conditioner.

Advantages of On/Off controllers

- Such controllers have three main advantages:
- low cost,
- instant response and
- ease of operation. However, it is important to ascertain that the upper and lower limit values are acceptable for a specific process.

Disadvantages of On/Off controllers

- It is not suitable for controlling any process parameter likely to suffer large sudden deviations from the set point and
- The quality of control is inferior to the continuous controller.

4.8.2 Proportional (P) Controller

- P-controller is one of the most commonly used controllers
- Produces an output signal to the final control element that is proportional to the difference between the set point and the value of the measured process parameter given by the sensor (this difference is also known as controller error or offset)
- Mathematically, it can be expressed as:

Where cos(t) COS(NE) + KC Et

COS(t) is the controller output signal at any time t, COS(NE) is the controller output signal when there is no error,

K_C is known as the controller gain or sensitivity (controller tuning parameter) and

E_t is the controller error or offset.

Proportional Integral Controller

Output signal to the final control element can be mathematically expressed as:

Where $$COS_{(t)} = COS_{(NE)} + K_C E_t + \frac{K_C}{\tau_I} \int E_t dt$$

τ is a tuning parameter called the reset time; and the remaining notations are same as in P I controller equation

Advantage

- The consequence of this is that integral action enables the PI controller to eliminate the offset, which is the key advantage of the PI controller over a P controller.

Disadvantage

- Two tuning parameters interact and it is difficult to find the 'best' tuning values once the controller is placed in automatic mode.
- A PI controller increases the oscillatory behavior.

4.8.3 Proportional Integral Derivative Controller

- Output signal to the final control element can be mathematically expressed as:

$$COS_{(t)} = COS_{(NE)} + K_C E_t + \frac{K_C}{\tau_I} \int E_t dt + K_C \tau_D \frac{dE_t}{dt}$$

- Where τ_D is a new tuning parameter called the derivative time; and the remaining notations are already explained above.
- Higher values of D provide a higher weighting to the fourth, i.e. derivative term which determines the rate of change of the controller error (E_t) whether E_t is positive or negative.

Advantage

- The introduction of the derivative term, is that it modifies the drawback of the PI controller
- it works to decrease the oscillating behavior of the measured process parameter.
- A properly tuned PID controller action can achieve a rapid response to error (proportional term), offset elimination (integral term) and minimize oscillations (derivative term).

Disadvantage

- The key disadvantage of the PID controller is that it has three tuning parameters, which interact and must be balanced to achieve the desired controller performance as it is often hard to determine which of the three tuning parameters is dominantly responsible for an undesirable performance.

4.9 Process Control in Modern Food Processing

- Control applications in food processing can be discussed in the context of three categories of products:
- Bulk commodity processing, e.g. grain milling, milk, edible oil, sugar and starch production, where control is arguably most advanced,
- Manufactured products, e.g. pasta, cheese, in-container and aseptically processed products, and
- Products which have been subjected to processing methods essentially designed to retain their original structure, e.g. meat, fish, fruits and vegetables.

4.9.1 Programmable Logic Controller

- It is a microprocessor-based system which can communicate with other process control components through data links. PLCs commonly use the so called ladder logic which was originally developed for electrical controls using relay switches.

4.9.2 Supervisory Control and Data Acquisition

- The supervisory control and data acquisition (SCADA) system is not a full control system, but is a software package that is positioned at a supervisory level on top of hardware to which it is interfaced, generally via PLCs, or other hardware modules.

4.9.3 Manufacturing Execution Systems

These are software packages which have been used for a number of years in process industries to support key operations and management functions ranging from data acquisition to maintenance management, quality control and performance analysis.

4.10 Spoilage due to environment

Foods used by human being and animals are contaminated, as stated earlier, by heterotrophic microorganisms to meet their nutritional requirements. The undesirable alterations brought about in foods by such microorganisms are referred to as ‘spoilage’.

4.10.1Factors (conditions) That Invite Food-spoilage:

As stated earlier, the variety of variety of microorganisms contaminates natural food substan-ces. The type of food substances and the methods by which they are processed and preserved favours the contamination. Most of the microorganisms prove to be potential contaminants and most of the foods serve as good media for microbial growth. These microorganisms, when given a chance to grow, bring changes in natural properties such as appearance, flavour, odour etc. of the contaminated food thus causing spoilage. Two major factors that invite spoilage of foods are the storage conditions and the chemical properties of the food.

Spoilage Due to Storage Conditions:

Temperature and oxygen are considered two most important factors that invite microbial contamination resulting in' spoilage of foods in storage conditions.

a. Role of temperature:

Foods stored at below - 17°C remain free from microbial growth and a slew decrease in their population may even take place. Above this temperature the presence and multiplication of microorganisms in food remain in existence. This is the reason why refrigerated foods are subject to spoilage by microorganisms. Foods and food-items stored at room temperature or in warm conditions remain open for spoilage by rnesophilic and thermophilic microorganisms.

b. Role of oxygen:

Aerobic and anaerobic condition plays an important role in determining the kinds of microorganisms, which can multiply and spoil various food and food-items in storage conditions. If oxygen is available, various aerobic bacteria and molds cause spoilage chiefly surface spoilage whereas if the conditions are anaerobic anaerobic bacteria like Clostridium spp. Etc.

4.10.2. Spoilage due to Food's Own Chemical Properties:

The chemical conditions of foods influence the type of microorganisms which can grow over it and. hence determine the nature of changes that would be brought by the spoilage action of contaminating microorganisms. Four major chemical conditions of food, e.g., composition, acidity, moisture and osmotic concentration are of the major importance in this type of spoilage.

a. Chemical composition:

(i) Foods rich in proteins are degraded by Proteolytic microorganisms. Proteins are degraded into its various components due to the action of especially gram-negative, spore forming bacteria, e.g.,Proteus, Pseudomonas, some cocci etc.

Protein foods + Proteolytic à Amino + Amines + Ammonia + (H_2S).

(ii) Foods rich in carbohydrates are degraded by carbohydrate fermenting microorganisms, particularly yeasts and molds. Bacteria like

Micrococcus,

Leuconostoc andStreptococcus can also degraded

carbohydrates. Carbohydrate + Carbohydrateà Acids

+ Alcohols +Gases Foods fermenting

microorganisms

(iii) Foods rich in fats are attacked by relatively few microorganisms such as mold and some gram-negative bacteria. These microorganisms are therefore, lipolytic in nature.

Fatty foods + Lipolytic microorganisms à Fatty acids+

Glycerol b. Acidity:

Generally the fruits are acid foods (pH below 4.5) while nearly all vegetables, fish, meats and milk-products are non-acid (pH above 4.5). Since the pH of the acid foods (fruits) is sufficiently low, they do not allow bacterial growth and subsequent spoilage. Mainly yeasts and molds spoil them. Contrary to this, non-acid foods have sufficiently high pH, they are spoiled mainly by bacteria.

c. Osmotic concentration:

Average 13% free water is required in food for usual microbial growth. This is the reason why the foods of high sugar and salt concentration do not allow most of the microorganisms to grow. But, specific microbial growths cannot be over-ruled. 65-70% sugar concentration is required to prevent mold-growth and 50% to prevent bacterial and yeast growth.

Moisture content (water activity, a_w)

Microorganisms need a moist environment to grow in. The water requirements of microorganisms are described in terms of water activity (represented by the symbol a_W), a measure of how much water is present. The water activity of pure water is a_W = 1.00. Most foodborne pathogenic bacteria require a_W to be greater than 0.9 for growth and multiplication; however, Staphylococcus aureus may grow with a_W as low as 0.86. But even Staphylococcus aureus cannot grow and multiply in drier food like bread, which has a_W = 0.7,

pH

pH is pronounced 'pee-aitch'.

The scientific term pH is a measure of how acidic or alkaline an environment is, on a scale that has 'neutral' (neither acid nor alkaline) at pH7. Environments that are acidic have pH values below 7; those that are alkaline have pH values above 7. Most microorganisms grow best at close to the neutral pH value (pH 6.6 to 7.5). Only a few microorganisms grow in very acid conditions below a pH of 4.0. Bacteria grow at a fairly specific pH for each species, but fungi grow over a wider range of pH values. For example, most meats naturally have a pH of about 5.6 or above. At this pH meat is susceptible to spoilage by bacteria, moulds and yeasts; however the pH of meat can be lowered by pickling, which makes it less favourable as an environment for microorganisms to grow in.

4.11 Microbial Spoilage Of Different Foods

The diet of many people is supplemented with food items preserved by special methods and available in a variety of conditions and stages of preparation. Such food may be frozen, canned or dehydrated; it may be partly or completely baked or pre-cooked, ready for heating and serving. During preparation, heterotrophic microorganisms for meeting their nutritional requirement can attack such foods. The unrestricted growth and multiplication of these microorganisms in food may render it unfit for consumption and can result in spoilage or deterioration.

The inner tissues of healthy plants and animals are free of microorganisms. They become contaminated when exposed to the microorganisms. The magnitude of this microorganism contamination depends upon various factors such as the microbial population of the environment from which the food was taken, the condition of the raw product, the method of handling the food and the conditions of storage.

Fruits and Vegetables:

Fruits and vegetables are generally contaminated by bacteria including species of Bacillus, Enterobacter, Lactobacillus, Leuconostoc, Pseudomonas, Sarcina, Staphylococcus, Streptococcus etc. Various molds and yeasts also inhabit the fruits and vegetables.

Contamination through infection:

Fruits and vegetables are normally susceptible to bacterial, fungal and viral infections. These infections invade the fruit and vegetable tissue uring various stages of their development and result in the subsequent spoilage.

Contamination through post-harvest handling:

Usually, mechanical handling of fruits and vegetables during post-harvest period produces 'breaks' in them which invite microbial invasion. Since the pH of the fruits is relatively acidic (i.e. high in sugar), they are more susceptible to fungi in contrast to vegetables, which are more susceptible to bacteria because of their pH being slightly higher (5.0 to 7.0; less in sugar).

Cereals:

Cereals and cereal products contain microorganisms from insects, soil and other sources. Bacillus, Lactobacillus, Micrococcus, Pseudomonas etc. are the bacteria, which are generally found on freshly harvested grains.

Mostly bacteria such as species of Bacillus, Lactobacillus, Micrococcus, Sarcinq, Serratia, coliforms etc contaminate wheat flours. Molds like Aspergiltus, Penicilltum are also very common

Meats:

The interior portions of meat are usually free of microbial contaminations if healthy animal is properly slaughtered. The fresh cut meat gets immediately contaminated with microorganisms derived from globes, hands, implements used to cut the meat, hides, hairs, intestines of the animals and the air of the slaughter house. Each new surface of meat, resulting from a new cut, adds more microorganisms to the exposed tissue. The more common microorganisms occurring on fresh, meats include both bacteria and molds. Bacteria such as species of Bacillus, Clostridium, Escherichia, Pseudomonas, Lactobacillus, Micrococcus, Streptococcus. Sarcina, Salmonella occur most commonly. Molds that contaminate fresh meat include Cladosporium, Geotrichum, Mucor, and Penicillium Sporotrichum etc. Yeasts are less commonly occurring.

Eggs:

Clean eggs with uncracked shell normally do not contain microorganisms within. Poor sanitary and storage conditions under which it is held determine its subsequent microbial content. Bacteria and molds may enter the egg through cracks in the shell. The microbial flora recovered from the eggshells generally includes the species of bacteria Micrococcus, Pseudomonas, Streptococcus, Staphylococcus, Sarcina; and the molds.

Poultry:

The surface of freshly dressed eviscerated poultry has microbial flora, which is derived from the live birds or from the manipulations during killing, defeathering and evisceration. Species of Bacillus, Enterobacter,

Escherichia, Proteus, Pseudomonas, Salmonella; and Staphylococcus constitute the major microbial flora on the skin of freshly dressed eviscerated poultry.

Fish:

The microbial flora of freshly caught fish usually reflects the microbial conditions of water from where they are harvested. Fish micro flora includes bacteria like Alcaligenes, Micrococcus, Pseudomonas, Serratia, and Vibrio etc. When the fish are cleaned and cut on shipboard under poor handling conditions, they invite more microorganisms to grow on it. These microorganisms can be exemplified by the species of Achromonobacter, Bacillus, Micrococcus, and Pseudomonas etc.

4.12 Microbial Contaminations Of Processed Foods

The quality and quantity of microorganisms associated with processed food including baked and fermented ones depends upon the ingredients used and processing methods. Microorganisms present in flour, sugar, fat, milk, egg, water, colors, man handling and the instruments etc. may contaminate the baked food products. Spore forming bacteria may escape destruction and become responsible for ropiness in breaked bread during baking process. The ropiness of the bread is caused by Bacillus subtilis or Bacillus licheniformis. Further, the baked products are subject to contaminate by molds such as Mucor, Rhizopus, and Aspergillus etc. Microorganisms through air, man and equipment contaminate the fermented foods like pickles. Most of these organisms do not multiply, as the reaction of the medium is considerably acid. Some yeasts and yeast-like forms such as Torula, Oidium etc., which are acid, tolerate establish in these foods on exposure.

4.13 Food Preservation

Food preservation is an effective way of saving food and preventing it from being wasted or lost. In fact, communities around the world have been employing food saving methodsfor centuries in order to prolong its shelf life.

The Incas historically introduced the production of chuños to South America. It was a way to preserve potatoes by exposing a frost-resistant potato variety to the very low night temperatures of the Andean Altiplano, freezing them, and subsequently exposing them to the intense sunlightof the day. Kiviak is a traditional wintertime Inuit food from Greenland that is made of auks (seabirds) preserved in the hollowed-out body of a seal and which are served at feasts or weddings. Bakkwa, a Chinese salty-sweet dried meat, was traditionally made with the leftover meats from festivals and banquets. The meat from these celebrations is trimmed of the fat, sliced, marinated and then smoked.

The Turkish horsemen of Central Asia used to preserve meat by placing slabs of it in pockets on the sides of their saddles, where it would be pressed by their legs as they rode. This pressed meat was the forerunner of today’s pastirma, a term which literally means ‘being pressed’ in Turkish, and is the origin of the Italian pastrami.

Cheese is an ancient food whose origin, predating recorded history, is assumed to lie in the practice of transporting milk in bladders made of ruminants' stomachs, with their inherent supply of rennet.

Earthen pots served as good preservation of boiled/mashed food which could remain fresh for several days. The food could be kept in a well aerated store/place called "Ikumbi".

In Andhra Pradesh, India, tamarind or lemon juice are used as preservative for chutneys, pickles and food that is packed for long journeys.

According to Harvard Univ. biological anthropologist Richard Wrangham, food processing was launched about 2 million years ago by a distant ancestor who discovered cooking, the original form of food processing (Wrangham 2009). Later, but still during prehistoric times, cooking was augmented by fermenting, drying, preserving with salt, and other primitive forms of food processing, which allowed groups and communities to form and survive. Humans thus first learned how to cook food, then how to transform, preserve, and store it safely. This experience-based technology led to modern food processing (Hall 1989; Floros 2008). Much later, the domestication of plants and land cultivation became widespread, and at the end of the last Ice Age, humans revolutionized eating meat by domesticating animals for food. Thus, plant and animal agriculture also contributed to improving the human condition.

Study of every ancient civilization clearly shows that throughout history humans overcame hunger and disease, not only by harvesting food from a cultivated land but also by processing it with sophisticated methods. For example, the 3 most important foods in Ancient Greece—bread, olive oil, and wine—were all products of complicated processing that transformed perishable, unpalatable, or hardly edible raw materials into safe, flavorful, nutritious, stable, and enjoyable foods (Floros 2004). Today, our production-to-consumption food system is complex, and our food is largely safe, tasty, nutritious, abundant, diverse, convenient, and less costly and more readily accessible than ever before. This vast food system includes agricultural production and harvesting, holding and storing of raw materials, food manufacturing (formulation, food processing, and packaging), transportation and distribution, retailing, foodservice, and food preparation in the home. Contemporary food science and technology contributed greatly to the success of this modern food system by integrating biology, chemistry, physics, engineering, materials science, microbiology, nutrition, toxicology, biotechnology, genomics, computer science, and many other disciplines to solve difficult problems, such as resolving nutritional deficiencies and enhancing food safety.

The impact of modern food manufacturing methods is evident in today's food supply. Food quality can be maintained or even improved, and food safety can be enhanced. Sensitive nutrients can be preserved, important vitamins and minerals can be added, toxins and antinutrients (substances such as phytate that limit bioavailability of nutrients) can be removed, and foods can be designed to optimize health and reduce the risk of disease. Waste and product loss can be reduced, and distribution around the world can be facilitated to allow seasonal availability of many foods. Modern food manufacturing also often improves the quality of life for individuals with specific health conditions, offering modified foods to meet their needs (for example, sugar-free foods sweetened with an alternative sweetener for people with diabetes).

Although today the public generally embraces and enjoys key benefits of the food supply—value, consistency, and convenience—some suggest that the cost to society of obtaining these benefits is too high. Negative perceptions about “processed foods” also exist, especially among consumers in the United States. A range of factors contributes to these perceptions. These include uneasiness with technology, low level of science literacy, labeling, and advertising that have at times taken advantage of food additive or ingredient controversies, influence on perception of voluntary compared with involuntary nature of risk, and high level of food availability (Slovic 1987; Clydesdale 1989; Hall 1989). Other factors contributing to negative public perceptions about processed foods include the increasing prevalence of obesity in many industrialized or developed countries, use of chemicals in production or additives in foods, little personal contact between consumers and the agricultural and food manufacturing sectors, food safety issues, and concern that specific ingredients (particularly salt), may contribute to illnesses or impact childhood development (Schmidt 2009).

During the 2009 World Summit on Food Security, it was recognized that by 2050 food production must increase by about 70%—34% higher than it is today—to feed the anticipated 9 billion people (FAO 2009a). This projected population increase is expected to involve an additional annual consumption of nearly 1 billion metric tons of cereals for food and feed and 200 million metric tons of meat.

Another challenge is the large, growing food security gap in certain places around the world. As much as half of the food grown and harvested in underdeveloped and developing countries never gets consumed, partly because proper handling, processing, packaging, and distribution methods are lacking. Starvation and nutritional deficiencies in vitamins, minerals, protein, and calories are still prevalent in all regions of the world, including the United States. As a consequence, science-based improvements in agricultural production, food science and technology, and food distribution systems are critically important to decreasing this gap.

In addition, energy and resource conservation is becoming increasingly critical. To provide sufficient food for everyone in a sustainable and environmentally responsible manner, without compromising our precious natural resources, agricultural production must increase significantly from today's levels and food manufacturing systems must become more efficient, use less energy, generate less waste, and produce food with extended shelf life.

Although scientific and technological achievements in the 20th century made it possible to solve nutritional deficiencies, address food safety and quality, and feed nearly 7 billion people, further advancements are needed to resolve the challenges of sustainably feeding the growing future population in industrialized and developing nations alike. In fact, to meet the food needs of the future, it is critically important that scientific and technological advancements be accelerated and applied in both the agricultural and the food manufacturing sectors.

4.14 Achievements and promises

The next section of this review, "Evolution of the Production-to-Consumption Food System," summarizes the parallel developments of agriculture and food manufacturing from the beginnings of modern society (the Neolithic revolution) to the present; it also addresses the current diet and chronic disease challenge. The subsequent section, "Food Processing: A Critical Element," explains why food is processed and details the various types of food processing operations that are important for different food manufacturing purposes. Then the following section, "Looking to the Future," outlines suggestions to improve our food supply for a healthier population, and briefly discusses the various roles that researchers, consumers, the food industry, and policy makers play in improving the food supply for better health; it also addresses the promises that further advancements and application of technologies in the food system hold for the future.

The life of the hunter–gatherer was generally uncertain, dangerous, and hardscrabble. Thomas Hobbes, in hisLeviathan(I561), described life in those times as "the life of man in a state of nature, that is, solitary, poor, nasty, brutish, and short." Agriculture transformed that existence by making available a far larger and generally more reliable source of food, in large part through domestication and improvement of plants and animals.

Domestication leads to civilization

Domestication is the process of bringing a species under the control of humans and gradually changing it through careful selection, mating, and handling so that it is more useful to people. Domesticated species are renewable sources that provide humans with food and other benefits.

At the end of the last Ice Age, humans domesticated plants and animals, permitting the development of agriculture, producing food more efficiently than in hunter-gatherer societies, and improving the human condition. Domestication did not appear all at once, but rather over a substantial period of time, perhaps hundreds of years. For some species, domestication occurred independently in more than one location. For animals, the process may have begun almost accidentally, as by raising a captured young animal after its mother had been killed and observing its behavior and response to various treatments. Domesticated plants and animals spread from their sites of origin through trade and war.

The domestication of plants and animals occurred primarily on the Eurasian continent (Smith 1998). A prominent early site was in the Middle East, the so-called Fertile Crescent, stretching from Palestine to southern Turkey, and down the valleys of the Tigris and Euphrates Rivers, where barley, wheat, and lentils were domesticated as early as 10000 y ago and sheep, goats, cattle, and pigs were domesticated around 8000 y ago. Rice, millet, and soy were domesticated in East Asia; millet, sorghum, and African rice in sub-Saharan Africa; potato, sweet potato, corn (maize), squash, and beans in the Americas; Asiatic (water) buffaloes, chickens, ducks, cattle, and pigs in the Indian subcontinent and East Asia; pigs, rabbits, and geese in Europe; and llamas, alpacas, guinea pigs, and turkeys in the Americas.

The introduction of herding and farming was followed by attempts to improve the wild varieties of plants and animals that had just been domesticated. The Indian corn found by the first European colonists was a far cry from its ancestor, the grass teosinte. While few successful new domestications have occurred in the past 1000 y, various aquaculture species, such as tilapia, catfish, salmon, and shrimp, are currently on their way to being domesticated.

Although the primary goal of domestication (ensuring a more stable, reliable source of animal and plant foods) has not fundamentally changed, the specific goals have become highly specialized over time. For example, we now breed cattle for either beef or dairy production, and cattle and hogs for leaner meat. We breed chickens as either egg layers or broilers. In addition, selection for increased efficiency of producing meat, milk, and eggs is prominent in today's agriculture, as discussed later in this section.

Agriculture, built on the domestication of plants and animals, freed people from the all-consuming task of finding food and led to the establishment of permanent settlements. What we know as civilization—cities, governments, written languages, an expanding base of knowledge, improved health and life span, the arts—was only possible because of agriculture. Along with domestication of plants and animals, people began the journey of discovery of methods to extend the useful life of plant and animal food items so that nourishment could be sustained throughout the year. With a fixed (nonnomadic) population also came primitive food storage and, with that, improvements in food safety and quality.

In July 2009, an important discovery and conjecture was made about the recognition that food security was of paramount importance. Kuijt and Finlayson (2009) reported that they believe they have discovered several granaries in Jordan dating to about 11000 y ago. This would suggest that populations knew the importance of having a dependable food supply before the domestication of plants. The authors further suggested that "Evidence for PPNA (Pre-Pottery Neolithic Age) food storage illustrates a major transition in the economic and social organization of human communities. The transition from economic systems based on collecting and foraging of wild food resources before this point to cultivation and foraging of mixed wild and managed resources in the PPNA illustrates a major intensification of human-plant relationships." Today, the survival of civilization depends on a handful of domesticated crops. Of the roughly 400000 plant species existing today (Pitman and Jorgensen 2002), fewer than 500 are considered to be domesticated.

Selecting for desirable crop traits

The primary force in crop domestication and subsequent breeding is selection, both artificial and natural, described below. Charles Darwin, in developing the theory of natural selection, relied heavily on the knowledge and experiences of plant and animal breeders (Darwin 1859). Crops were domesticated from wild ancestors' gene pools that had been altered by selection imposed by early agriculturalists and by natural selection imposed by biotic and abiotic environmental factors (Harlan and others 1973; Purugganan and Fuller 2010). Selection changes gene pools by increasing the frequency of alleles (genes encoded by a place in the genome and that may vary between individuals and mutant/parent strains) that cause desirable traits and decreasing the frequency of alleles that cause undesirable traits. Modern crop varieties are still shaped by the same forces.

The causes of the bursts of domestication activity have been the subject of much speculation (Smith 1998), but the changes symptomatic of domestication are well established for many species (Harlan and others 1973; Doebley and others 2006). Legumes and the large-seeded grasses collectively known as cereals (for example, maize, wheat, rice, and sorghum) contribute most of the calories and plant protein in the human diet. For these and other annual crops such as sunflower and squash, the initial changes during domestication involved ease of harvesting and the ability to compete with weeds. Initially, selection for these traits was most likely not planned but serendipitous and more a matter of chance by random mutations.

The most significant problem confronting most agriculturalists, both early and modern, is weed competition. Early agriculturalists scattered seeds on ground that had been prepared, most likely by burning or some other disruption of the soil surface. Those seeds that passed their genes onto the next generation (natural selection) were those that best competed with weeds. Selection pressure due to weed competition results in a number of changes, including the reduction or elimination of seed dormancy and larger seeds (Harlan and others 1973; Smith 1998). Dormancy is very undesirable in annual crops, and most domesticated species germinate rapidly upon planting. Selection against dormancy has been so extreme, however, that under certain weather conditions, seeds of modern wheat varieties (Triticum aestivum) and barley (Hordeum vulgare) sprout while still in the seed head, destroying the value of the grain crop. Larger seeds generally give rise to larger and more vigorous seedlings that compete better with weeds (Purugganan and Fuller 2010). In the grasses, selection for larger seed size is associated with increased starch and decreased protein in the endosperm. For example, the protein content of teosinte (Zea mays parviglumis)—the wild ancestor of maize (Zea mays mays), which is referred to as corn in North America—is approximately 30%, while the protein content of modern maize is 11% (Flint-Garcia and others 2009).

While the goal of selection is to alter the targeted trait (appearance and/or performance) and the genetic variation underlying the selected trait will be reduced over time, unselected traits will also often change, and these changes may be negative (for example, reduced endosperm protein in grasses that have been selected for larger seeds).

For example, in the United States, the major selection criterion for maize is increased grain yield (Tracy and others 2004), and strong selection pressure for increased grain yield leads to increased starch content and decreased protein content (Dudley and others 2007). Critics focus on such changes as evidence that the quality of our food supply has been "damaged" by modern plant breeding and agricultural practices. But has it? In United States agriculture, maize is grown for its prodigious ability to convert the sun's energy into chemical energy (carbohydrates), while we have abundant sources of plant and animal protein. In other parts of the world, maize is a staple crop, and diets of many people are deficient in protein. To improve the nutrition of the poor whose staple is maize, plant breeders at the Intl. Center for Maize and Wheat Improvement (Centro Internacional de Mejoramiento de Maíz y Trigo, CIMMYT) developed quality protein maize (QPM) that has an improved protein content and amino acid profile (Prasanna and others 2001). It is the selection of the breeding objective that determines the outcome. Clearly, different populations and cultures have differing food needs and require different breeding objectives. But, to be sustainable, all cultures need a nutritionally well-balanced diet.

Changes in food animal agriculture and fisheries

Animal food products are good sources of high-quality protein, minerals (for example, iron), and vitamins, particularly vitamin B12, which is not available in plant materials. Livestock production is a dynamic and integral part of the food system today, contributing 40% of the global value of agricultural output, 15% of total food energy, and 25% of dietary protein and supporting the livelihoods and food security of almost a billion people (FAO 2009b). Seafood, including products from a growing aquaculture segment, provides at least 15% of the average animal protein consumption to 2.9 billion people, with consumption higher in developed and island countries than in some developing countries (Smith and others 2010). Except for most of sub-Saharan Africa and parts of South Asia, production and consumption of meat, milk, and eggs is increasing around the world, driven by population and income growth and urbanization (FAO 2009b; Steinfeld and others 2010). The rapidly increasing demand for meat and dairy products has led during the past 50 y to an approximately 1.5-fold increase in the global numbers of cattle, sheep, and goats; 2.5-fold increase in pigs; and 4.5-fold increase in chickens (Godfray and others 2010). The nutritional impact of animal products varies tremendously around the world (FAO 2009b; Steinfeld and others 2010).

The structure of the livestock sector is complex, differs by location and species, and is being transformed by globalization of supply chains for feed, genetic stock, and other technologies (FAO 2009b). The current livestock sector has shifted from pasture-based ruminant species (cattle, sheep, goats, and others having a multichamber stomach, one of which is the rumen) to feed-dependent monogastric species (for example, poultry) and is marked by intensification and increasing globalization (Steinfeld and others 2010). A substantial proportion of livestock, however, is grass-fed (Godfray and others 2010) and small-holder farmers and herders feed 1 billion people living on less than $1 a day (Herrero and others 2010).

The rates of conversion of grains to meat, milk, and eggs from food animals have improved significantly in developed and developing countries (CAST 1999). Technological improvements have taken place most rapidly and effectively in poultry production, with broiler growth rates nearly doubled and feed conversion ratios halved since the early 1960s. In addition to these productivity gains, bird health and product quality and safety have improved through applications of breeding, feeding, disease control, housing, and processing technologies (FAO 2009b). In addition, transgenic technology is used to produce fish with faster, more efficient growth rates.

The application of science to agriculture has dramatically increased productivity, but until the Green Revolution of the 1960s and 1970s, productivity was not keeping pace with population growth. Large areas of the world, including the 2 most populous nations, China and India, were experiencing severe food shortages and anticipating worse. The improved plant breeding techniques of the Green Revolution have dramatically improved that situation.

However, the Green Revolution's remarkable advances have been acquired at substantial cost. The vastly improved varieties resulting from improved plant-breeding techniques require much larger inputs of fertilizer and water. Poor farmers often cannot afford the fertilizer, and adequate water supplies are becoming an increasing problem in many areas. Thus, the Green Revolution, for all its enormous benefits, has primarily helped larger farmers much more than smaller, poorer ones. In addition, pesticide applications in the developing world are too often inappropriate or excessive—in some cases because the farmer is unable to read the label—and there is no structure (for example, a regulatory agency such as the Environmental Protection Agency) to regulate their use.

Problems are not, however, confined to the developing world. Nutrient run off in the United States and other countries leads to algal blooms in lakes and estuaries and to “dead zones” completely lacking in oxygen in lakes and oceans. Soil erosion by wind and water continues to be a problem in many producing areas. Soil quality thus suffers. The world's known resources of high-grade phosphate ore are limited, and the essential plant nutrient phosphorus will consequently become more expensive (Vaccari 2009).

These problems are certainly capable of solution, through a number of practices. Beneficial options include "no-till" agriculture (which leaves the root systems of previous crops undisturbed, thereby retaining organic matter and greatly discouraging erosion), integrated pest management, IPM (which focuses pesticide use where needed, substantially decreasing the amount used), precision agriculture (which site-specifically targets production inputs such as seed, fertilizer, and pesticides where and when needed), drip irrigation (controlled trickling of water), and use of new technology for recovering nitrogen and phosphorus from processing wastewater for use as fertilizer (Bongiovanni and Lowenberg-Deboer 2004; Frog Capital 2009; Gebbers and Adamchuk 2010).

Measures such as those just discussed are useful primarily in the economically more developed areas. Developing countries require other steps adapted to their local areas and focused particularly on improvements for the many millions of small, poor farmers. Improved plant varieties, produced both by conventional breeding and through biotechnology are necessary, as are improved varieties of fish and livestock. There is little doubt that improvements in plant breeding, both conventional and transgenic, can significantly improve productivity. Technological improvements, such as automated plant monitoring via robotics, are "helping plant breeders trim years off the process of developing crop varieties tailored to local conditions" (Pennisi 2010).

The list of such needs is far too long to explore here, but it also must include public health measures. A major problem yet to be addressed is the subsidization of agricultural products in developed nations. Products from small, unsubsidized farmers in developing nations cannot compete in the world market with subsidized products from advanced nations. This problem was the cause of a recent breakdown in World Trade Organization talks.

Some see organic agriculture as an answer to these problems. Organic farming has some clear merits, particularly those practices, such as crop rotation and the use of green or natural biocontrol agents and animal manure, which have been used by farmers for millennia (King 1949). The use of degraded plant and animal residues increases the friability (tendency to crumble, as opposed to caking) and water-holding capacity of soil, and nutrients from decaying plants and animal manure are more slowly available than those from most commercial fertilizers. Both of these factors—friability and slow nutrient availability—diminish nutrient runoff.

While organic agriculture continues to grow in response to consumer preferences in the developed world, there are limitations to widespread use of organic practices. Organic agriculture requires substantially more land and labor than conventional practices to produce food, and the resulting yields are not great enough and too expensive to address the needs of the growing population. The supply of composted animal manure is limited and relatively expensive compared to commercial fertilizers. Organic agriculture excludes the use of synthetic pesticides, and the few “natural” ones that are permitted are seldom used (Lotter 2003). Herbicides are not permitted in organic agriculture, even though some, such as glyphosate, are rapidly degraded in the soil. These exclusions require more manual labor for weed and pest control. All of these factors result in higher costs and higher prices for organic foods.

Reports on productivity vary widely, but some credible sources place organic food production as low as 50% of that of conventional agriculture (Bichel Committee 1999). Yield differences may be attributable to a number of factors such as agro-ecological zone (for example, temperate and irrigated compared with humid and perhumid), crop type, high-input compared with low-input level of comparable conventional crop, and management experience (Zundel and Kilcher 2007). In addition, current organic methods exclude the use of the products of modern biotechnology—recombinant DNA technology—essential to future increases in agricultural productivity. Nevertheless, the more useful practices of organic agriculture must be part of the agriculture of the future.

Although poverty and malnutrition exist in all countries, by far the most severe problems in achieving availability, safety, and nutritive value of food and beverages occur in the developing world (IFPRI 2009). Water shortages and contaminated water, poor soil, destruction of forest for fuel, use of animal manure for fuel, the spread of plant and animal diseases, and the complete lack of a sound food safety infrastructure are among the most vexing problems. Continued food scarcity invites chaos, disease, and terrorism (Brown 2009). The gap between developing and developed nations is not only in economics but also in science, governance, and public information. Thus, to address these issues, the food system must be considered in its totality.

Eighty percent of agricultural land is used for grain fed to meat animals and yields only 15% of our calorie intake. Many have suggested that world food shortages could be greatly alleviated by consuming less meat and using the grain supplies now consumed by animals more directly. Reduction in meat intake, particularly red meats, would confer some health benefits, but the potential effects on world food supplies are less clear and quite possibly much less than many presume. If developed nations consume much less meat, the price of meat will fall and poorer nations will consume more. If more grain is consumed, grain prices will rise, to the detriment of populations that already rely heavily on grain. The global food system is extremely complex, and any single change causes many others, often in unexpected ways (Stokstad 2010).

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DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – V – FOOD TECHNOLOGY – SCH1609

PRODUCTION AND UTILIZATION OF FOOD PRODUCTS

All living beings require nutrients to perform various functions of life. While plants can prepare them from simple chemicals present in the soil and the environment, higher organisms can not perform this synthesis and have to depend on plants and other animals for their nutritional requirements. Body performs several functions related to growth and development and it has to cope up with the normal wear and tear process. Several nutrients are required for promoting these activities which should be available in sufficient quantity. But no single food contains all the nutrients; their nature and quantity vary with the source. Improper diet may result in deficiency of one or more of these nutrients. Nutritional deficiencies reduce mental and physical efficiency of people and increase their susceptibility to diseases.

5.1 Fruits and Vegetables

Fruits and vegetables posses rich colour and have varied aroma. They add variety to the food, and improve aesthetic appeal of the diet. Fruits and vegetables are generally consumed for their aesthetic appeal but their nutritional significance is not fully realized by the consumers. They are rich sources of vitamins, minerals and dietary fibre. Dietary fibre (hemicelluloses, celluloses, lignins, oligosaccharides, pectin, gums and waxes) though resistant to digestion play an important role in human health. They do not provide nutrients directly, but low dietary fibre have been associated with diseases like cardiovascular diseases, obesity, diabetes, constipation, bowel cancer, etc. Daily intake of 30 g dietary fibre by a normal healthy adult has been suggested. Fruits and vegetables, in general, contain 1.0 to 2.2 % fibre and contribute up to 50% of dietary fibre. Fruits and vegetables, contribute about 90% of total dietary ascorbic acid, 50% of vitamin A, 35% of riboflavin, 25% of magnesium, 20% each of thiamine and niacin, 20% of fat, 7% protein and 10% of food energy.

Nutritional composition of fruits and vegetables depends on species, variety, location, season and agro-climatic conditions. Moreover, nutrient loss also occurs during storage, preparation and processing. Consumer may not be aware of these changes. Fortification helps in standardizing fruit and vegetable products to a pre-decided level of nutrients. It also enables processors to fortify the products to meet the nutrient requirements of specific group of people such as sport persons and athletes.

Information about the nutrient content is given on the label of container on the basis of a serving. The term ‘serving’ denotes that quantity of a food in a meal which is suitable for consumption by an adult male doing light physical activity. Unit of 'serving' should be understandable to common consumer, such as cupfuls, teaspoonfuls, etc.

5.2 Beverages

The term beverage includes fruit juices, squashes, nectars, ready to-serve beverages, carbonated beverages or aerated waters, synthetic juices, fruit juice concentrates and dry instant drinks. Beverages are the most commonly fortified fruit and vegetable products. They are fortified with vitamin C and to some extent with vitamins A and B. or vitamin A, the substance used is beta carotene, which is a precursor of this vitamin and also gives colour to the juice.

Methods used for food fortification with nutrients are as follows:

i) *Dry mixing:* It is used for foods like salt, beverage powders, cereal products, milk powder, etc.

ii) *Dissolution in water:* The nutrients are dissolved in water or the product and mixed, e.g., fruit juices, beverages, drinks, etc.

iii) *Spraying:* Processed foods that require cooking or extrusion like potato chips, fruit bars, etc.

iv) *Dissolution in oil:* Oily products such as vanaspati are enriched by nutrients dissolved in oil.

v) *Adhesion:* It is used for sugar fortification. Vitamin A in powder form is adhered onto the surface of the sugar crystals when used with a vegetable oil.

vi) *Coating:* The vitamins sprayed over the grain must be coated to avoid losses when they are washed before cooking. It is generally used in case of rice.

vii) *Pelleting:* It is also used for rice. The vitamins are incorporated into pellets reconstituted from broken kernels.

Sources of vitamins are used, though blending with aonla juice as a source of vitamin C and carrot juice as a source of beta carotene can also be carried out. Losses of vitamins may take place during processing. Therefore, contact of fruit juice with iron and copper should be minimized by using stainless steel or glass lined equipments and vessels and juice should be de-aerated before pasteurization.Vitamins, particularly thiamin, folic acid and vitamin C, are sensitive to heat. Beverages fortified with these vitamins must not be over heated; their temperature should be kept at 90^0C or less for a maximum period of 15 seconds. Fortification of beverages with vitamin A, folic acid and calcium pentothenate present problems because these nutrients are very unstable at pH around 3.0, which is normal pH of most fruit juices. Further, solubility of folic acid in water is very low.Vitamin premix is dispersed in juice/ beverage, before homogenization step. Subsequent step of homogenization insures thorough mixing of vitamins in beverage.Amount of vitamin C added should be such that each serving of 110-170 ml provides about 40 mg, which is the minimum daily requirement of an adult. Since some of the vitamin C may be lost during processing and storage, its 35-70% extra amount is added. In other words, total amount of vitamin C should be 54 to 68 mg per serving.

5.2.1 Fortified apple juice

Apple juice contains only 0.2-0.6 mg vitamin C per 100 ml as compared to 9.7-70.0 mg per 100 ml in orange juice. Further, colour of apple juice is light after extraction. But colour of juice becomes dark within 1 hour due to action of enzyme polyphenol oxidase on tannins of juice in the presence of air. Apple juice is fortified with vitamin C to raise its vitamin C content and to utilize oxygen present in the head space. Removal of oxygen from headspace checks oxidation of tannins and thus prevents discoloration of juice. But fortified apple juice, when exposed to oxygen, starts loosing vitamin C at the rate of 1 to 4 mg per 100 ml per day and its colour may again become dark. Therefore, it should be protected from air.

Vitamin C is added at the rate of about 70 mg per 100 ml at the time of extraction when apple juice comes out of press. Excess amount of added vitamin C may get degraded during processing and storage but it ensures that 40 mg of this vitamin per 100 ml remains in the juice.

5.2.2 Fortified orange juice

Vitamin C content of orange juice varies from 27 to 67 mg/ 100 ml depending upon location of orchard, variety, etc. Therefore, orange juice is fortified so that it provides the minimum recommended amount of 40 mg vitamin C per serving.

5.2.3 Fortified fruit juice concentrates and powders

Fruit juice concentrates and powders serve as base for various fruit beverages. They are easy to store and transport and reduce packaging requirements as compared to juices and other beverages. But during preparation, fruit juices are heated for long period which results in greater loss of vitamins. Therefore, they are fortified. High TSS of concentrates protect vitamins and reduce loses during storage. Synthetic orange juice concentrates are prepared using orange pulp and rind. Other ingredients
added are gum *arabic*, cellulose gum, natural and synthetic flovours, artificial colour, potassium citrate and calcium phosphate. It is fortified with vitamin A, B and C.

Fortified fruit juice powders are prepared from fruits like apple, peaches, cherry, etc., by foam-mat drying process. In this process solubilized soy protein and methyl cellulose is added to fruit pulp.

Instant dry mixes of beverages and juice powder are fortified with vitamins by dry mixing. Water dispersible forms of vitamins are used. Mixing must be complete but over mixing should not be done because it results is segregation.

5.2.4 Fortified carbonated beverages

Many carbonated beverages are fortified with vitamin C. During carbonation process, CO_2 expels the air. Removal of air and oxygen increases stability of this vitamin. Fortification of carbonated beverages with vitamin C improves nutritional value of the beverage, and some of it react with and remove residual oxygen from the head space of bottle which extends shelf-life of the beverage. Theoretically, 3.3 ml of vitamin C reacts with 1 ml of air. An overdose of vitamin C should be added to carbonated beverages to compensate for the losses.

5.2.5 Fortified banana powder

Banana powder fortified with soy protein can be used as a weaning ford for babies. To prepare it, whole soybeans are blanched in boiling water for 30 min, ground into fine paste with 10 times its weight of water and mixed with ripe banana pulp. Ratio of banana solids and soy solids in paste is kept equal. To the blend 100 ppm sodium meta bi-sulphite is added which prevents darkening. The paste is dried to 3% moisture level over a drum drier.

5.2.6 Fortified jellies

To fortify jellies, a concentrated vitamin premix is prepared and some sucrose is added. Fat soluble vitamins are used in water dispensable forms. Vitamin premix is added to the jelly near the end point but before addition of citric acid. Vitamin C reduces the pH of jelly which may prevent their setting. Therefore, pectin jellies are not fortified with vitamin C.

5.2.7 Fortified fruit cloth and fruit bar

Fruit cloth and fruit bars are products prepared from fruit pulp and concentrates by sun drying or drum drying. Fruit clothes from apples, apricots, dates, mango, papaya, etc., are prepared. ‘Amavat’ or ‘Ampapar’ is traditionally prepared in India by sun drying ripe mango pulp in the sheets, the thickness of sheet is gradually increased. The fruit bars can be moulded into different forms. They may be pre-treated with SO_2, viz., 0.5% sodium bisulphite. Sulphur dioxide improves colour and protects vitamin C and beta-carotene. Level of total soluble solids in pulp is raised to about 30% by adding sugar, also reduces drying time. Depending upon requirement, citric acid is added to improve the taste and acceptability of
fruit bars. It can be fortified with protein powders (skim milk powder, whey protein isolate, ground nut or soy protein isolate, yeast protein), vitamins and other nutrients. Fortification is done by adding nutrients to the pulp concentrate and then drying it or spread the nutrient premix over the surface of dried fruit material.

5.3 Legal Standards

These are also called as Health Ministry (Government of India) standards and are mandatory in nature. They are prescribed to ensure minimum quality in the foods marketed and promulgated under the Prevention of Food Adulteration Act other Rules and Orders of Government of India which cover food items: beverages, starchy foods, spices and condiments, sweetening agents, edible fats, milk and milk products, common salt, fruit products, edible oils, cereal products, vanaspati, vinegar, sweets and confectionary, food colours, limits for preservatives, antioxidants, emulsifying and stabilizing agents, flavouring agents, pesticide residues.

Degree of excellence of a product is indicated in terms of grades, standards and specifications which are laid down by a competent authority in the country. It is an important consideration in marketing of a product. Consumers are concerned about the safety, nutritional quality, aesthetic value, convenience to use and cost of foods. An established system of quality control assures uniformity in standards and thereby ensures that each food stuff is what it possess to be and what its label declares, if there is one.

5.4 Market Standards

The market dictates some quality parameters in the food stuffs marketed. There can be more than one quality requirement for a particular commodity. The economic status and quality consciousness of the consumer influences the market standards and they are voluntary in nature. Examples are different, grades of fruits, vegetables, rice with more or less broken, pulses etc.

5.5 Industry Standards

These standards require special quality factors in the foods the consumer purchase. Wheat miller requires wheat with high milling yield. A baker will require a wheat flour with high percentage of gluten of good strength to obtain a good loaf of bread. Similarly fruit processing industry will require certain specific qualities in the fruits like colour, flavour when they are purchased.

5.6 Evaluation

The quality evaluation of fruits, vegetables, other foods and processed products gives useful information on nutritional and biochemical characteristics. Quality evaluation methods can be destructive or non-destructive. They include both objective (based on instrument readings) such as physical, chemical, or microbiological and subjective (based on human judgment, using hedonic scales) methods as in taste. Subjective methods are also called as sensory analysis.

The physical, chemical and microbiological analytical methods are considered to be objective. These methods are usually standard scientific tests, which, one should be in a position to reproduce with the same results by any trained technician. Physical measurements include product attributes such as; size, weight, colour, texture, headspace and even impurities such as filth and insects. Chemical methods are usually more complex and often require sophisticated instrumentation. Precise tests for moisture, total soluble solids, titratable acidity, vitamins, colour pigments, proteins, carbohydrates, ash, pectin and fiber have become standard practice. Microbiological methods are used to determine the presence of bacteria, moulds and yeasts.

5.7 Testing Methods

5.7.1 Acoustic and vibration tests: The sound of a fruit as it is tapped sharply with a finger knuckle can change during maturation and ripening and this method is used by consumers while purchasing fruits. Melons are trapped to judge whether they are ready to be harvested.

5.7.2 Electrical properties: Electrical properties of the fruit change with the soundness or maturity or spoilage or physical damage of the fruit. It has been found that the capacitance of deteriorated cell increased while resistance decreased and therefore the measurements could be used to determine the freshness or age of the fruit. At 500 Hertz the dielectric constant of green and ripe peaches was 550 and 150 respectively.

5.7.3 Nuclear magnetic resonance (NMR): NMR is being used to find the maturity & quality of fruits and it is also correlated well to sugar content of bananas & apples, and oil content in avocado. It has been used to detect bruises on apples, peaches, pears and onions, pits in olives and prunes and insect damage in pears.

5.7.4 Near Infrared Reflectance (NIR): It has been studied to measure the internal qualities like sugars, acidity, soluble solids, nitrogen & calcium in apples, peaches, pineapples, mango and pear. It is used to find the fruit firmness & their storability in cold stores.

5.7.5 Sonic techniques: Based on the generation of resonating frequency that can be used to calculate internal resistance (hardness).

5.8 Grading and Certification

The fruits, vegetables and other foods are graded according to size, shape, weight, colour and visible defects to obtain uniform quality and fetch good price for the fruits. This is done by hand or machines. Automatic grading machines are available in which vibrating screens or screens with various sized slots are used to separate different types of product. *Density grading* is carried out by using different concentration of brine for fruits. Grading for colour is carried out by an electronic colour-sensing device. Manual grading done by hands and is usually necessary to avoid losses or to keep losses within reasonable limits.

To ensures quality and purity, Government of India, has established different agencies like AGMARK, Indian Standard Institute to make grades of foods, vegetables & fruits and they are affixing their marks (Agmark, ISI) on the products. The quality *of* product is determined with reference to the size, variety, weight, colour, moisture and, fats content and other factors. The act defines the quality of most of the agricultural raw and processed products commodities into various grades depending upon the degree of purity in each case. The grades incorporated are grades 1, 2, 3 and 4 or special, good, fair and ordinary. The physical and chemical characteristics of products are kept in mind while formulating the Agmark specifications.

Grading of commodities like ghee, butter, vegetable oils, *atta*, spices and honey is voluntary. On the other hand, grading of spices, basmati rice, essential oils, onions, potatoes etc. that are meant for export, is compulsory under AGMARK to ensure quality. The grading of agricultural commodities has three main purposes to: (i) to protect the producers and consumer from exploitation. By knowing the quality and grade of his produce, he is in better bargaining position against the trader. (ii) serve as a means of describing the quality of the commodities to be purchased *or* sold by the buyers and sellers in the country and abroad. Which avoids the need for physical checking and handling at many points. (iii) protect the consumer by ensuring the quality of products he purchases.

Under Indian Standard Specification fruits and vegetables have three grades, super, fancy and commercial.

Fruits and vegetables under this grade shall be of similar variety characters, fresh, firm, i.e. not withered or wilted, tender, succulent, well shaped, fairly smooth clean and well coloured which means that the commodity has a uniform good colour characteristics of the variety over practically the entire surface, well developed, uniform in size, free from injuries and damage by scars, insects, diseases or mechanical or other means.

Fancy: The fruits and vegetables under this grade shall be of similar variety characters, fresh, firm, tender, succulent, well shaped, fairly smooth clean and well coloured. And are free from, injuries, damage by disease, insects, mechanical or other means.

Commercial: The fruits and vegetables under this grade shall consists which do not conform to the requirements of either super or fancy grade, but the quality is fit for use of human consumption.

The Bureau of Indian Standards, (BIS) Act, 1986, operates a product certification scheme, including Food and Agriculture. The certification allows the licensees to use the popular ISI Mark, which has become synonymous with Quality products for the Indian markets.

The BIS certification is voluntary, and aims at providing quality, safety and dependability to the customer. All BIS certifications are carried out on Indian Standards, which have been found amenable to product certification. Presence of certification mark known as Standard Mark on a product is an assurance of conformity to the specifications. The conformity is ensured by regular surveillance of the licensee's performance by surprise inspections and testing of samples, drawn both from the factory and the market.

The Govt. of India on considerations of public health & safety, and mass consumption has enforced mandatory certifications of 135 products through Orders issued under various Acts. While the Bureau grants licenses only on application however the enforcement of compulsory certification is done by the notified authorities and the Bureau maintains a close vigil on the quality of goods certified through its surveillance operations.

The broad area of food and agriculture under certification are: processed fruits and vegetable products, spices and condiments, bakery, confectionery and nutritious supplements, dairy products, drinks and carbonated beverages, fish and fisheries products, food additives, food analysis and nutrition, food hygiene, food microbiology, food grains, livestock feeds, oils and oilseeds, pesticides residue analysis.

To safeguard the interest of the consumer, it is necessary to have a check and control over the quality of food marketed for human consumption.

In India “Prevention of Food Adulteration Act” was promulgated by the Government in 1954 and the Rules under this act were made in 1955. The act was intended to make provisions for the prevention of adulteration in food. The act empowers the government agencies to prevent this unsocial activity and safeguard the health of the people. The implementation of the Act/Rules is done at State/Union territory level whereas the Central Government may give such directions it may deem necessary regarding execution of the provisions in the Act/Rules. For this purpose, the ‘Central Committee for Food Standards’ was constituted with (a) members representing concerned ministries, (b) representatives of consumers, medical professionals, agricultural, commercial and industrial organizations and hotel industry, (c) representatives of State/Union territories and (d) Directors of the Central Food Laboratories and (e) Director General of Health Services. Four Central Food Laboratories and a number of state level laboratories were established for analysis of samples collected by the state level food inspectors.

Standards under PFA Act and Rules: The standards laid down under the PFA Act and Rules are minimum standards of purity and are based on the agricultural practices, climatic conditions prevailing, and economic conditions and nutritional status of the people in the country

The standards are mandatory in nature and by government laws food articles which do not conform to the standards are considered unfit for human consumption. The Act and Rules deal with preservatives, poisonous metals, naturally occurring toxic substances, anti-oxidants, emulsifying and stabilizing agents, flavouring agents, colouring matter and other food additives, insecticides and pesticides, solvent extracted oils and edible flours, non-alcoholic beverages, starchy foods, spices and condiments and their mixes, honey, jaggery, saccharin, coffee, tea and milk, milk products, edible oils, cereals, baked products, sweets and confectionary and a range of similar products. The Act and Rules deal with the administrative procedures to be followed for reporting, analysis, prosecution, presentation of cases in a court of law and punishment to be carried out.

Quality of food is a combination of attributes, properties or characteristics that give a commodity value in terms of human food. The important components of quality are: appearance, texture or firmness, flavour, colour, purity and nutritional quality. Food plays a very significant role in human nutrition especially as source of carbohydrate, protein, fats, vitamins, minerals and dietary fibre. Lipid oxidation and non-enzymatic browning in fruits and vegetable are two major chemical characteristics, which affect the quality of food during processing and storage. The microbiological characteristics are associated with the presence of bacteria, yeasts and moulds on foods resulting in deterioration of quality.

Different quality standards are formulated and enforced by Government of India to ensure food quality and safety for human consumption. The quality
evaluation of fruits, vegetables, other foods and processed products gives useful information on nutritional and biochemical characteristics and can be determined by destructive or non-

destructive methods. These include both objective such as physical, chemical, or microbiological methods and subjective such as taste. Food adulteration is defined as the process by which the quality or the nature of a food product is adversely affected through the addition of a foreign or an inferior substance and the removal of a vital element. Adulteration may be intentional or unintentional. In India “Prevention of Food Adulteration Act” was promulgated by the Government to make provisions for the prevention of adulteration in food by law.

The fruits, vegetables and other foods are graded according to size, shape, weight, colour and visible defects to obtain uniform quality which is done by hand or machines. Automatic grading machines are available. Grading for colour, an electronic colour-sensing device is used. To ensures quality and purity, Government of India, has established Agricultural Produce Grading and Marketing Act (Agmark), and Indian Standard Institute to make grades of foods, vegetables and fruits & they are affixing the Agmark & ISI quality mark respectively on the products. The Bureau of Indian Standards, (BIS) Act, operates a product certification scheme, including Food and Agriculture. The certification allows the licensees to use the ISI Mark, which insure quality of products. The BIS certification is voluntary, and aims at providing quality, safety and dependability to the customer. All BIS certifications are carried out on Indian Standards, which have been found amenable to product certification.

5.9 Emerging novel processes

To meet consumers’ growing demands for fresh-like and highly nutritious foods with guaranteed safety, several alternative preservation technologies have been developed during the past 15 to 25 y for application to food products. These technologies include both (1) novel thermal processes such as microwave and ohmic heating, which are much faster than the currently widespread canning method to produce shelf-stable foods and (2) other physical methods that do not use heat as a primary mode of inactivating microorganisms in foods, such as ultra-high pressure (UHP), pulsed electric fields, ultrasonic waves, high-intensity pulsed light, and others.

Each of these alternative technologies has unique characteristics and potential for expanded applications in different categories of food products. The goal of all the new processes is to reduce the overall time and temperature exposures of the foods so that they are safe and more like fresh or freshly cooked items. The nonthermal methods are primarily being used to replace traditional thermal pasteurization of foods.

- Microwave Heating. This method of heating prepared foods and beverages and cooking raw foods is well known and accepted by consumers, but applications for food preservation are still evolving.

Some microwave-processed foods are marketed in Europe and Japan. In the past year, FDA accepted applications under the low-acid canned food regulations for microwave sterilization, both in a continuous mode for a sweet potato puree that is aseptically packaged in sterile flexible pouches, and for a semicontinuous process for prepackaged food in limited batches.

• Ohmic Heating. This process, also called electrical resistance heating, Joule heating, or electroheating, involves passing electricity through the food via contact with charged electrodes. The electrical energy results in rapid, uniform heating, in contrast to the slow conduction and convection heating of conventional thermal processing, thereby allowing for greater quality than canned counterparts. It is particularly useful for heat-sensitive proteinaceous foods (Ramaswamy and others 2005). Ohmic heating has been applied in limited situations to such foods as cut and whole fruit and liquid eggs, but applications may expand to soups and similar items in the future.

• High-Pressure Processing. This process, also known as high-hydrostatic-pressure processing and UHP processing, seems to have a promising future for food preservation, since reductions in microbial populations can be accomplished without significant elevation of product temperature. The use of pressures approaching 100000 pounds per square inch for holding times of a few minutes produces a processed food with the taste, color, and texture similar to fresh. Following the successful introduction of a pressure-treated guacamole product in 1997, a growing number of ready-to-eat meats and other refrigerated items, including raw oysters, have been treated by high pressure to meet food safety standards for such products and have increased their high-quality shelf life.

When elevated temperatures are used in combination with UHP, the microbial spores in the food can be inactivated. In 2009, a pressure-assisted thermal sterilization process developed by a consortium of Army and industrial researchers at the Natl. Center for Food Safety and Technology was accepted under the low-acid canned food regulations by FDA (NCFST 2009). This process is more rapid and less damaging to several food quality attributes than traditional thermal sterilization because application of pressure rapidly and uniformly heats packaged food in the pressure vessel to the desired end temperature, and then, when pressure is released after a few minutes the product returns to the original temperature.

• Pulsed Electric Fields. Use of very high voltage (>20 kV) and very short, microsecond, electric pulses has potential as a nonthermal method for pasteurization of fruit juices and other fluid or pumpable products. The process is being optimized, but more information needs to be evaluated on the impact of the process on food components, first to assure microbiological safety and then to determine the impact on sensory quality as well as content of key nutrients (Sanchez-Moreno and others 2009).

Recent research has shown not only that some of these alternative novel processes allow production of very high quality items, but also that those items may have a higher nutritive value than similar items produced by traditional thermal processes because the novel processes result in less chemical damage of key micronutrients.

To achieve acceptance first by the regulatory authorities and then by consumers will require an overall evaluation of each of these novel processes.

Food waste management

Approximately 30 to 40% of raw food materials and ingredients are lost between the points of production and consumption. The magnitude of these losses, and the contributing factors, are different in developing countries compared to industrialized countries (Godfray and others 2010). For example, food losses in the developing world are primarily due to the lack of an infrastructure, as well as lack of knowledge of or investment in the means to protect from losses arising from damage and spoilage attributable to rodents, insects, molds, and other microorganisms. Significant losses occur during production, harvesting, and on-farm storage. In contrast, in industrialized countries, food losses are more significant in retail and foodservice establishments and in the home. The losses in developed countries are attributable to several factors, including the relatively low costs of food and the lack of incentives to avoid wastes (Godfray and others 2010).

Commercial food manufacturing operations are more efficient in the conversion of raw materials into consumer products than home processing and preparation. Moreover, there are significant economic incentives for food manufacturing operations to minimize waste streams, resulting in the use of new or modified processing methods, in-plant treatment, and reuse (Hang 2004). Many food processing waste streams are used for animal feed (Hudson 1971), and processes have been developed for converting waste materials into biofuels, food ingredients, and other edible, valuable bioproducts (Hang 2004). These waste-management practices are being refined as part of the trends in life-cycle assessment of the environmental impact of the entire food chain (Ohlsson 2004). Through such assessments, the food industry is identifying the steps in the food chain that have the greatest environmental impact. The assessments become the basis for selection of alternative raw materials, packaging materials, and other inputs, and an overall improvement in waste-management strategies (Ohlsson 2004).

Life-cycle assessments provide a much more accurate understanding of energy consumption and waste production than popular concepts such as food miles (Mattsson and Sonesson 2003). An example of life-cycle assessments is the comparison of high value added products, such as pork, with a highly productive crop, such as potatoes. The analysis indicates that for the high value added product, the largest energy consumption and production of emissions and other wastes is in the agricultural sector (that is, on the farm). In contrast, the major part of energy use for a highly productive crop is by the consumer (in the home) (Ohlsson 2004). Thus, to reduce energy contributions to global warming and generation of pollutants, it would be appropriate to target reductions where they would have the greatest effect (for example, on the farm for items such as pork and in the home for items such as potatoes) rather than simply focusing on food miles or food processing.

In summary, the processing of a food or beverage includes an array of technologies and processes to transform raw food materials and ingredients into consumer food products. The primary purpose of these processes is for preservation (for example, transforming perishable fruits and vegetables with the highest quality outcome possible into products available throughout the year around the world) and to ensure food safety.

The processing of a food does create some changes in the quality attributes of the product. In some cases, these changes are intentional and provide improvements in the nutritive quality, texture, appearance, and flavor of the product. In other cases, the changes may simply make the product different, without improving or changing its quality.

Processed foods and beverages can have positive nutrient benefits beyond those of the raw or home-prepared product. Nutrient retention is highly variable, depending on commodity, cultivar, timing of harvesting, storage conditions, nutrient type (for example, sensitivity to heat or oxygen, and water solubility), and processing method. Depending on these variables, processed foods may have more nutritional value (due to greater bioavailability of beta-carotene or lycopene, for example) than the fresh product (Rickman and others 2007a, 2007b). In addition, some processed products (for example, canned and frozen fruits and vegetables) are often a better value for the consumer than the "fresh" or raw product.

Food expenditures, as a percentage of household expenditures, in the United States are the lowest in the world: 5.6% compared to 9.1% in Canada, 11.4% in Germany, 24.1% in Mexico, and 44.1% in Indonesia (ERS 2008). Cost is an extremely important variable to most consumers in making food and other purchases, particularly to those with low incomes. Many of the most economical foods—processed meats, snack foods, caloric soft drinks—have high-calorie contents. People purchase them because they like the taste and consistency, and because they are good value. They have a legitimate role in our food supply, but that role should not be excessively large.