Lecture 34: Food Technology

34.1 Introduction

Food technology has evolved into an interdisciplinary area of applied science and engineering based on chemical engineering and food science. India is primarily based on agriculture. The demand for uniform and high quality food round the year even at remote places from production centre has led to improved food processing technologies. Food industries are almost double the size of chemical industries.

34.2 Food industries can be divided into following sections:

- Consumer food industry (confectionaries, cocoa products, bakery products, soft drinks etc.)
- Grain processing
- Marine products
- Dairy products
- Poultry and meat products
- Fruit and vegetable processing
- Fats and oils
- Sugar

34.3 Emphasis of food industries

Food industries emphasize on four different operations namely food storage, food processing, food transport and food preservation.

(i) Food storage

Food storage includes improved storage of food such as refrigeration cycles, refrigerants, and better insulation. Food industries process the raw materials as soon as they are recovered. Sometimes due to unavoidable circumstances such as early arrivals, non-availability, market price considerations which change according to time, the raw materials have to stored before processing.
The storing area should be well ventilated, shaded, should use water baths, and if necessary, cold storage must be used. Before storage, all bruised, shriveled, discolored or soured portions should be removed.

(ii) **Food Processing**

Food processing involves conversion of raw plant and animal tissues into edible ingredients and separation of inedible and hazardous components, extraction or concentration of nutrients, flavors, colors and other useful components and removal of water.

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**Types of food processing:**

(a) Refining and Milling  
(b) Canning  
(c) Concentration  
(d) Freezing  
(e) Drying  
(f) Pasteurization and sterilization  
(g) Fermentation  
(h) Irradiation  
(i) Packaging

(a) **Refining and Milling:**

- Sugar obtained from sugar cane is converted to final sugar by refining process.
- Milling is the process of converting grain into powder (flour) by mechanical means.
- In milling operation, grain is cleaned and crushed between two steel rolls.
(b) Canning:

- Fresh food like fruits, vegetables, meat, fish etc. are preserved for long time storage by heat treatment and sealing into air-tight containers.
- These cans may be made by tin, untinned steel, which is often plastic-lined, aluminium or glass.
- Heat treatment is given to the container by placing them in a steam pressure vessel at a temperature of 121°C depending on container size and nature of food.
- The toxin produced by microorganism is clostridium botulinum. Therefore processing must be done to destroy this organism.

(c) Concentration:

- Foodstuff which naturally contains high percentage of water is concentrated before preservation.
- Milk is evaporated from 8.6% solid content to 45% solid content.
- Fruit juices are also concentrated before marketing.
- Usually the volume is reduced to one-third of the original volume.
- For food concentration three processes are available—evaporation with evaporators, reverse osmosis and freeze concentration.

(d) Freezing:

- Freezing does not kill the microorganisms which cause spoilage, but freezing inactivate microorganisms.
- Nutrients are not destroyed by freezing.
- Inactivation of enzymes by heat treatment (blanching) is done before freezing to prevent unwanted changes.
- To improve the quality of final product, the amount of water in food is reduced before freezing.
(e) Drying:
- Cereal grains, fruits, pastas, milk, coffee, tea, some vegetables and meats are dried.
- After drying volume is reduced to one tenth of the original volume.
- Dried foods are easy to transport and store.
- The nutritive value of dried food is usually unchanged but vitamin content is reduced.
- Microbial growth is controlled.

(f) Pasteurization and sterilization:
- Heat treatment inactivates the microorganisms but changes the taste of food and its appearance.
- The high temperature short time (HTST) method exposes the milk to 73°C for not less than 16sec, followed by rapid cooling. This process is called pasteurization.
- Pasteurization kills pathogenic (disease causing) microorganisms, eliminates food borne disease and inactive enzymes.
- Milk can be stored for several months at room temperature.

(g) Fermentation:
- All organisms are not detrimental.
- Fermentation produces carbon dioxide but no putrid odor.
- Fermentation is decomposition of carbohydrate.
- These industries produce vinegar, wine, beer and other alcoholic beverages. It is also used in making bread, cheese, salting of food etc.

(h) Irradiation:
- Irradiation is required to kill microorganism present in food.
- Irradiation is used to preserve proteinous food such as meat, fish, fresh fruits, vegetables, flour, spices etc.
- Irradiation does not denature protein, does not alter taste and does not leave any radioactive residue in the food.
- Loss of vitamins is less as compared to canning, freezing or drying.

(i) Packaging:
- The objective of packaging is to store and transport safely without deterioration of food.
- Containers are sealed so that no outside contaminant can enter and cause food spoilage.
- Cardboard boxes, cans, glass bottles, polythene, plastic coated paper, finely woven cloth are commonly used for packing.

References:

Dryden C. E., Outlines of Chemical Technology, East-West Press, 2008

Lecture 35

35.1 Food Processing Equipments

(a) Sanitary Design and Material of construction

- Hygienic or sanitary design of food processing equipment is based on proper selection of material of construction and fabrication techniques.
- Chemical and biological properties also play an important role in designing of equipments in food industries.
- The major problem is corrosion and toxicity of food products due to corrosion.
- pH of food products should also be considered for material selection.
- Stainless steel is widely used for being corrosion resistant.

Three A have set standard special features for design of equipment to ensure sanitary conditions. These are as follows:

- Material, in general, should be 18-8 stainless steel, with a carbon content of not more than 0.12%, or equally corrosion-resistant material.
- The gage of metal should be sufficient for various applications.
- Product surfaces fabricated from sheets should have a No.4 finish or equivalent.
- Square corners should be avoided. Minimum radii are often specified. For example, a storage tank must have inside corners of 6.4mm for permanent attachments.
- No threads should be in contact with food. Acme threads should be used.
- Surfaces should be sopped to provide drainage.
- Designs should permit interchangeability of parts.

(b) Cleaning

- Cleaning is an integral part of food processing operation.
- The process should ensure the microbiological safety of final products.
- After cleaning, the surface should be washed with hot water and left to dry.
Three –A standards for cleaning in place are as follows:

- Using alkali or acid solutions appropriate for the product and equipment surface.
- Providing a time of exposure of 10 to 60 min to remove substances without damage to the metal.
- Utilizing a velocity of flow of 1.5m/s (1 to 3m/s).
- Maintaining a slope of surface and tubing to provide for drainage (5 to 10mm/m).
- Avoiding dead ends for flows.
- Using connections and joints that are cleanable (welded joints, clamp-type joints, appropriate gaskets).

(c) **Controls**:

- Continuous processes are better than batch operation to save processing cost and for better uniformity.
- Quality control is greatly improved by computer control.
- Cheese plant uses process control computer to regulate process.

(iii) **Food transport**:

It involves chemical engineers in designing refrigerated container, for transporting food products from the place of production to the consumers by rail and road carriers.

(iv) **Food preservation**

It means preserving final food products for longer use and storage with the help of chemical additives, freezing, drying, inert gas blanketing etc. Preservation operation reduce or eliminate food spoilage.
35.2 Tomato-paste processing plant

Tomato processing plant produces tomato paste. It includes various processing equipments and many unit operations and processes such as washing, inspecting, pulping, finishing, evaporation, sterilization, aseptic packaging and finally storage of tomato paste. A simplified process block diagram is shown in figure. Due to seasonal variability of raw tomato, material and energy balance are required periodically, during the operation of the food processing plant.

35.3 Potato chips processing plant

Solar energy is basically used for frying potatoes. The rising energy cost has necessitated using solar energy. Solar energy is collected through parabolic trough collectors to heat pressurized water. In steam flash heated water is converted to steam. The produced steam and steam from a gas-fired boiler is used to heat the fryer through a heat exchanger. To conserve energy, cogeneration of electricity with process steam is done to save about 20% of total energy.

35.4 Food Additives

Food additives improve nutritional compositions, flavor and storage stability in food products. It is used in small quantities. Food additives may be categorized with some of their examples. These are categorized according to functional and nutritional benefits provided to food rather than chemical identity of additives. Some of these are summarized as below.

**Acidulants:** eg. adipic acid, citric acid, fumaric acid, lactic acid, malic acid, phosphoric acid, tartaric acid.  

**Anticaking and free flow agents:** eg. Calcium silicate (CaSiO$_3$), Calcium stearate (C$_{36}$H$_{70}$CO$_4$), Magnesium silicate, Magnesium carbonate.  

**Antifoaming agents:** eg. Polydimethylsiloxane
**Antioxidants:** eg. Butylatedhydroxyanisole \((C_{11}H_{16}O_2)\), Propyl gallate \((C_{10}H_{12}O_5)\), Ascorbic acid,Erythorbic acid

**Bulking agents:** eg. Polydextrose

**Coloring agents:** eg. Beet powder, caramel, saffron titanium dioxide and FDA certified chemicals

**Dietary fibres:** eg. Cellulose, hemicellulose, pentosans, pectins

**Emulsifiers:** eg. Glycerol monostearate, succinylatedmonoglyceride, propylene glycolmonostearate, sodium stearoyl-2-lactylate, polyoxethylenesorbitan, monooleate, lecithin, sucrose esters.

**Enzymes:** eg. Amylase, glucoamylase, lactase, pectin methylesterase, lysozyme, lipase, tryipsin,glucose isomerase, glucose oxidase.

**Fat replacer:** eg. Protein, caprenin, caprylic acid.

**Firming agents:** eg. Calcium chloride, acidic aluminium salts.

**Flavors:** eg. Essential oils, fruit juices, aroma chemicals.

**Flavor enhancers:** eg. Monosodium L-glutamate, ammonium glycyrrhizinate.

**Flour bleaching agents and bread improvers:** eg. Benzoyl peroxide

**Formulation aids:** eg. Starches, dextrins, maltodextrin, mineral oils.

**Fumigants:** eg. Propylene oxide, ethylene oxide.

**Gases:** eg. Nitrogen, carbon dioxide

**Humectants:** eg. Polyhydric alcohols.

**Leavening agents:** eg. Sodium bicarbonate

**Non – nutritive sweeteners:** eg. Aspartame, saccharin.
**Nutrient supplements**: eg. Riboflavin, niacin, iron.

**Preservatives**: eg. Benzoates, sorbates, propionates, sulfur dioxide, sulfites.

**Processing aids**: eg. Gelatin, lime

**Solvents**: eg. Ethanol, glycerin, propylene glycol.

**Stabilizers and thickeners**: eg. Gaur gum, carrageenan, cellulose.

### 35.5 Technical Questions

1. **What are the byproducts of food industries?**
   
   **Ans**: Leather, gelatin and adhesives.

2. **How is effective pasteurization and sterilization processing carried out?**
   
   **Ans**: Heating alters the odor and taste of food and other chemical changes also take place. Short time-high temperature treatment causes less deterioration than long-time low temperature processes. To provide adequate heat penetration using a short time treatment, agitated cookers are used. Agitation increases the rate of heat transfer from container to food product.

3. **How effectively is freezing processing carried out?**
   
   **Ans**: For preservation of fresh food, food should be frozen very quickly (supercooled) and maintained at enough low temperature to prevent appreciable ice crystal formation. By this way, quality of food does not deteriorate and microorganisms do not increase to great extent. Generally slow freezing produces large ice crystals in the cells of the food which rupture the cells and cause a breakdown of the structure of the food and allows undesirable enzyme reactions even at a very low temperature (-18°C).
4. Why is vacuum evaporation preferred for juice concentration rather than evaporation at atmospheric pressure?

**Ans:** Vacuum evaporation involves evaporation of water from fruit juices at lower pressures. It is well known that the boiling point of a liquid increases with increasing temperature and hence processing at higher temperature would damage heat sensitive biological compounds in the juice. Therefore, vacuum evaporation will contribute towards achieving the boiling point of juice at temperatures close to the room temperature and thereby safeguard the nutritional content of the fruit juices.

5. What characterization methods are applicable for food process technologies?

**Ans:** Food chemistry and biotechnology related characterization methods need to be applied for the analysis of the concentration of various species contributing towards flavors and nutrition. Other than this, food process technologies also need to assess upon the toxicity of the processed food along with the maximum allowable shelf time, before the processed food is dangerous for human consumption.

**References:**

Dryden C. E., Outlines of Chemical Technology, East-West Press, 2008

LECTURE I - INTRODUCTION

1.0 HISTORICAL BACKGROUND

- Accidental discoveries of processes and attempt to control man’s environment.
- Passage of Food and Drug Act by the United States (U.S) congress (1906) catalysed by the study of food chemistry.
- Food Chemistry today.

1.1 DEFINITION OF FOOD CHEMISTRY

- The study of composition of foods and of the reactions which lead to changes in their constitution and characteristics.

1.2 BENEFITS DERIVABLE FROM THE STUDY OF FOOD CHEMISTRY

- Basic knowledge of the constituents of food.
- Determination of appropriate processing and preservation method.
- Aids understanding of microbiological reactions in food.
- Information on chemical reactions involving food.
- Useful information in New Food Product Development
- Useful information to Engineers in design and fabrication of appropriate food processing equipment.
- Help in choice of packaging material, equipment and technique.
- Useful in storage stability and shelf life studies of food and food products.

LECTURE 2

2.0 WATER IN FOODS

- Water as basic constituent of ALL foods.

2.1 FORMS OF WATER IN FOOD

- Free water/moisture
- Hydrates of water
- Imbibes water
- Adsorbed water

### 2.2 PROPERTIES OF WATER

- Structure and Bonds in water H2O, covalent and H-bonds.
- Some physical properties of water and ice.
  * Density
  * Vapour pressure
  * Refractive index
  * Viscosity
  * Specific heat
  * Heat of vapourization
  * Thermal conductivity
  * Dielectric constant
  * Coefficient of thermal expansion
  * Melting point
  * Boiling point.

### 2.3 WATER ACTIVITY

- The concept of water activity relates the moisture (water) in a food to the RH of the air surrounding the food and is defined as ratio of the partial pressure of water in a food to the vapour pressure of water at the same temperature.

\[
aw = \frac{P}{P_o}
\]

where 
- \( P \) = vapour pressure of water in food
- \( P_o \) = vapour pressure of pure water at the same temperature
- \( aw \) = Water Activity.

OR \( aw \) can be defined as the ratio of the vapour pressure of water in a food to the saturated vapour pressure of water at the same temperature.

i.e. \( \frac{P}{P_o} \) where 
- \( P \) (pa) = Vapour pressure of water in food
- \( P_o \) = Vapour pressure of pure water at the same temperature.
- \( aw \) = water activity

- for pure water \( aw = 1.0 \)
- High m.c. amount of moisture > that of solids, \( aw \leq 1.0 \)
- Adsorption process
Dry product subjected to increasing moisture levels in the surrounding/environment.

- Desorption process
  Moist product gradually equilibrating with lower moisture levels of the surrounding/environment.

- Hysteresis loop
  • Difference between adsorption and desorption isotherms.
  • It occurs because adsorption and desorption isotherms are more identical.

2.4 WATER ACTIVITY AND FOOD SPOILAGE
- Moisture content and $a_w$ are important factors which affect ratio of spoilage of food in terms of chemical, biochemical and microbiological reaction.
  - for M.c 5-15% - moist, dried foods (powdered)  - Great storage stability
  - M.C. 20-40% - Intermediate moisture foods  - less stable than dried foods.

2.4.1 Biochemical/Chemical Reactions Attached By $a_w$
- Most Enzymes are inactivated when $a_w < 0.85$ e.g. Amylases, peroxidases etc
- Lipases are still active at $a_w$ 0.3 or less.
- Maillard reactions occur at $a_w$ 0.6 – 0.7

2.4.2 Microbiological reactions
- Bacterial growth – Impossible at $a_w < 0.90$
- Molds and yeasts – Inhibited between $a_w$ 0.88 – 0.80
- Osmophilic yeasts can grow at $a_w$ of 0.65

LECTURE 3
3.0 PROTEINS
- Complex organic substances present in all living matter (plants, animals and microorganisms).
- ALL proteins, apart from consisting of C, H and O also contains N and sometimes may contain S as well as P.
3.1 **AMINO ACID**

- Structural units of all proteins are amino acids. General formula RCN (NH$_2$) COOH.
- There are 200 such amino acids.
  * Aliphatic monomerino monocarboxylic amino acids: Glycine, Alanine, Valine, Leucine, Isoleucine, Serine, Threonine and Proline.
  * Sulphure containing amino acids: Cysteine, cystine & methionine.
  * Mono a,omp Dicarboxylic amino acids: Aspartic acid and glutamic acid.
  * Basic Amino acids: Lysine, Arginine and Histidine.
  * Aromatic amino acids: Phenyl alanine, agrosine and Tryptophan.
  * Derivatives of other amino acids: 4–Hydroproline and 5-Hydrolysine.

3.1.1 **Properties of Amino acids**

- Optical Activity
- Zwitterion formation (Electrostatically neutral form).
- Isoelectric point – pH at which the amino acid consist of mainly Zwitterion e.g. for Glycine pHi = 5.97

3.2 **CLASSIFICATION OF PROTEINS**

- can be based on solubility, coagulation or prosthetic groups.
- Simple proteins
  proteins that will yield only amino acids on hydrolysis e.g. Asbamins, globalins, colutelins, protamines etc.
- Complex proteins
  Proteins that contains non-protein entities attached to the polypeptide chain e.g. phospoproteins, Glycoproteins, Lipoproteins, Chromoproteins, Nucleoproteins etc.

3.2.1 **Properties of Proteins**

- Amphoterism
- Solubility
- Colour Reactions e.g. Biuret reaction
- Hydrolysis using 6 mHCL, or 5MN₃OH or action of proteolytic enzymes.
- Oxidation Reduction reaction
- Sensory characteristics – Tasteless, odourless and Colourless.
- Molecular weight – they are High Mw cpds.
  e.g. Insulin – 5,700, Myosin – 620,000 Ribonuclease – 12,000.
- Structure of proteins – are joined by (prh) peptide bonds.
  * primary eg mw, aa composition and linear sequence of the aa residues
     along the polypeptide chain.
  * Conformation:
    - Secondary structure
    - Tertiary structure
    - Quaternary structure

3.2.2 **Protein Denaturation**

Term used to describe changes in the physico-chemical properties of soluble proteins. It can be described as any modification in the conformation of a protein.

- Factors that can cause protein Denaturation.
  - Heat
  - Strong acids (low pH)
  - Strong bases (High pH)
  - Some solvents such as ethanol
  - Conc solution of salts
  - Phenolic substances.

- Changes that may accompany denaturation
  - Coagulation (Loss of solubility)
  - Gel formation
  - Higher Digestibility (Higher susceptibility to Enzyme hydrolysis)

- Renaturation
  Reverse of denaturation (slow and practically irreversible).

- Application
  - Denaturation of Enzymes e.g. Blanching of fruit and vegetables.
    Pasteurization of milk etc.
LECTURE 4

4.0 BROWNING REACTIONS
Complex reactions which occur in food leading to formation of brown colour. It could be as a result of processing or storage of food. Two main types:
- Enzymic Browning
- Non-Enzymic

4.1 ENZYMIC BROWNING OF FOODS
Browning catalysed by enzyme, it occurs in the
- Presence of oxygen
- Phenolase Enzyme (or Polyphenol oxidases)
- Enzyme activity can be divided into 2:
  - The cresolase activity
  - The catecholase activity.

- Characteristics:
  - The enzymes are copper proteins and they are active in the monovalent form of copper.
  - pH of activity near 7
  - Fairly resistant to heat.

- Specificity of the Enzyme
  - Acts on monophenol or ortho-diphenol not on meta-diphenol.

- Reactions:
  - Crisolase activity – It acts as oxygen transferable in the hydrogenation of monophenol to polyphenol derivatives. Eg. Tyrasine – 3, 4 – dihydroxy phenyl Alamine (DOPA).
  - Catccholase activity.
Acts as a dehydrogenase enzyme in removing Hydrogen from substances.

DOSA – O. quinine phenyl Alamine,

- The quinine then forms DOPAchrome which polymerises to form melanin.

Application:
Common during processing of vegetable tissues that rich in polyphenols e.g yam.

4.1.2 **Control of Enzymic Browning**

Aim – To stop activity of phenolase enzyme.

Methods:
- Heat treatment e.g. Blanching
- Use of $\text{SO}_2$ – It inhibits phenolase enzyme.
- Use of acids.
  Eg. Ascorbic acid
  other acids e.g. Citric, Malic
- Removal of surface oxygen
- Use of salts e.g. Nacl solution
- Other methods e.g. Borate salts, HCN etc. Some of these may not be applicable to food because of some other effects e.g HCN in poisonous, boric/Borate salt may colour the food etc.

**LECTURE 5**

5.0 **NON-ENZYMIC BROWNING OF FOODS**

Browning that is not catalysed by enzyme. Three types exists:
- Maillard Reaction
- Caramelization
- Ascorbic Acid browning

5.1 **MAILLARD REACTION**

This type of browning involves reaction between sugars and amino acids (proteins). It occurs at high temperature. The reactions involved can be divided into 5 main steps:
- Condensation of sugars with amino compound.
- Rearrangement of condensation products (Amadori-rearrangement)
- Dehydration of rearrangement products leading to formation of furfural or its derivative (HMF).
- Degradation and fission reaction
- Polymerization of the products of degradation and fission into melanin/melanolin

5.1.1 **Application**
- Browning during food processing such as baking of bread, roasting of

5.2 **ASCORBIC ACID BROWNING**
Non enzymic browning phenomenon associated units fruit juices and concentrated especially discolouration of citrus products.
- Ascorbic acid browning can occur in the presence or absence of amino acids.
- Although mechanism of reaction is not very clear, it involves oxidation of Ascorbic acid in the presence of air to dehydroascorbic acid and subsequently to 2, 3-diketogulonic acid.
- The presence of oxygen tends to intensify colour formation until it reaches a maximum and then colour formation decreases in the presence of excess oxygen as if oxygen had a bleaching effect on the pigment formed.
- Among the intermediates identified:
  - furfural
  - 2-furoic acid
  - Threonic acid
  - Oxalic acid
  - L-erythro-pentosulose
  - Carbon dioxide

5.3 **CARAMELIZATION**
- Browning reactions of sugars in the absence of amino acids and at high temperatures >100°C. This temperature is higher than temperatures at which maillard reactions occur. It is otherwise called pyrolysis of sugars.
- Pyrolysis usually lead to formation of brown colour and characteristic flavours.
- It may be intentional or incidental during food processing.
- Catalysts.
Caramelization is catalysed by phosphates, alkalis, acids and salts of carboxylic acids of citrate, fumarate, tartarate and malate.

- Mechanism of reaction not totally clear but may be similar to that of sugar-amino browning and could involve:
  - Enolization
  - Dehydration
  - Fission

Leading to formation of Hydroxy-furfural (HMF).

5.4 **NUTRITIONAL EFFECT OF BROWNING**

- Irreversible binding of amino acids into complex pigments
- Destruction of amino acids through strecker degradation.

5.5 **PRACTICAL PREVENTION OF BROWNING**

- Refrigeration
- Use of chemicals e.g. \( \text{SO}_2 \)
- Low pH
- Lowering concentration
- Use of sucrose
- Fermentation

**LECTURE 6**

6.0 **LIPIDS**

Lipids are natural substances which are insoluble in water, but soluble in non-polar solvents such as hexane, benzene, carbon tetrachloride, ether etc. Chemically, they can be described as actual or potential derivatives of fatty acids or closely related substances.

6.1 **CLASSIFICATION**

- Simple lipids
- Composite lipids
- Sphingo lipids
- Derived lipids

6.2 SIMPLE LIPIDS

- Glyceryl esters
  They are formed as a result of esterification of glycerol molecule with fatty acid units. They can be:
  - Monoglyceride – glycerol + 1 Fatty acid
  - Diglyceride – glycerol + 2 fatty acid
  - Triglyceride – glycerol + 3 fatty acid

Most natural fats and oils are Triglycerides (TC₃)
If the TC₃ exists as solid at room temperature it is a FAT
If the TC₃ exists as liquid at room temperature it is an OIL

6.2.1 FATTY ACIDS

Aliphatic carboxylic acids. They can be divided into 2 main types:
- Saturated fatty acid (No double bond)
- Unsaturated fatty acid (Double bond present)
- Saturated fatty acids – are homologous series with a general formula and gradation in properties (physical and chemical) e.g. Butyric acid, caproic acid etc.
- Unsaturated fatty acids makes up the fatty acids contained in majority of oils from plant sources e.g. oleic acids, Linoleic acid, etc.
- Glyceryl resters can be simple or mixed TC₃
  Simple TC₃ have all the 3 fatty acid units the same.
  Mixed TC₃ have all the 3 fatty acid units different.
- Most natural fats and oils are mixed TC₃

6.3 PROPERTIES OF TRIGLYCERIDES

6.3.1 Physical properties
- Colourless, odourless, tasteless and water
  Insoluble – melting point – Refractive index
- Plasticity – Specific gravity – smoke, flash and fire prints etc.
6.3.2 **Chemical properties**
- Hydrolysis (Saponification)
- Oxidation (Antioxidation)
- Iodine value
- Acid/free fatty acid value etc.

**LECTURE 7**

7.0 **LIPID OXIDATION**
- Rancidity – Occurrence of off-flavours in fat containing foods.
- Antioxidation-spontaneous oxidation of a substance in contact with molecular oxygen.
- Consequences of lipid antioxidation.
  - Rancidity
  - Colour changes accelerated through browning reactions.
  - Impaired nutritional value of food
  - Toxicity
- Part most affected by lipid antioxidation is the unsaturated fatty acids and this becomes more pronounced as the number of double bonds increases.

7.1 **MECHANISM OF REACTION**

Step 1: Initiation

RH - activation R' + H'

Step 2: Propagation

R + O_2 - ROO

ROO + RH - R' + ROOH

Step 3: Decomposition

ROOH - RO' + OH' (also R', ROO' etc)

Step 4: Termination

ROO' + X - Stable

**Activation**

Note: The methylenic groups adjacent to a double bond of a fatty acid is particularly labile.
Eg. oleic

**Exercise:** find how many tree radicals may be formed by linoleic and Linolenic acids

### 7.2 RATE OF ANTIOXIDATION

(i) Rate of \( O_2 \) consumption (\( O_2 \) uptake)

OR

(ii) Accommodation of penoxides (rep by value) (PV)

(iii) OR determination of decomposition products (in form of oxidized fat)

(iv) Other methods – organoleptic tests.

### 7.3 EFFECTS OF ENVIRONMENTAL FACTORS

- Temperature in Q10 values for chemical reaction
  Affects rate of antioxidation and reaction mechanization
- Light- UV light is potent than white light
- Oxygen – without \( O_2 \) reaction me
  Stage 2 ( ) will be
- Moisture – Intermediate moisture (monolayer values) are more stable than either low or high m.c (released to air).
- Ionizing radiation e.g High energy rays (B & rays)
  (radiation induced free-radicals) may affect even saturated fats
- Catalysts
  - Metal catalysts – (ions of
  - Naturally
  - Enzymes (Li
- Antioxidants (oxidation)
  Naturally
A. Carbohydrate

Definition:
The term carbohydrate often means any food that is particularly rich in the complex carbohydrate starch (such as cereals, bread, and pasta) or simple carbohydrates, such as sugar (found in candy, jams, and desserts).

Composition:
A carbohydrate is an organic compound with the empirical formula $C_m(H_2O)_n$; that is, consists only of carbon, hydrogen, and oxygen, with a hydrogen:oxygen atom ratio of 2:1 (as in water). Carbohydrates can be viewed as hydrates of carbon, hence their name. Structurally however, it is more accurate to view them as polyhydroxy, aldehydes and ketones.

Function:
Carbohydrates serve several biochemical functions:
- Monosaccharides are a fuel for cellular metabolism.
- Monosaccharides are used in several biosynthesis reactions.
- Monosaccharides may be converted into space-saving polysaccharides, such as glycogen and starch. These molecules provide stored energy for plant and animal cells.

Carbohydrates are used to form structural elements, such as chitin in animals and cellulose in plants.
- The 5-carbon monosaccharide ribose is an important component of coenzymes (e.g., ATP, FAD, and NAD) and the backbone of the genetic molecule known as RNA. The related deoxyribose is a component of DNA.
- Saccharides and their derivatives include many other important biomolecules that play key roles in the immune system, fertilization, preventing pathogenesis, blood clotting, and development.

Classification and names:
- The carbohydrates (saccharides) are divided into four chemical groupings: monosaccharides (e.g glucose, fructose, galactose), disaccharides (sucrose, lactose), oligosaccharides, and polysaccharides (chitin, cellulose).
- In general, the monosaccharides and disaccharides, which are smaller (lower molecular weight) carbohydrates, are commonly referred to as sugars.
- The word saccharide comes from the Greek word σάκχαρον (sákkharon), meaning "sugar". While the scientific nomenclature of carbohydrates is complex, the names of the monosaccharides and disaccharides very often end in the suffix -ose.
- For example, blood sugar is the monosaccharide glucose, table sugar is the disaccharide sucrose, and milk sugar is the disaccharide lactose.

Characteristics used to classify monosaccharides:
- number of carbon atoms in the molecule
- location of the carbonyl group
The chirality of the carbohydrate

**aldose** - monosaccharide in which the carbonyl group is an aldehyde

**ketone** - monosaccharide in which the carbonyl group is a ketone

**triose** - monosaccharide with 3 carbon atoms

**tetrose** - monosaccharide with 4 carbon atoms

**pentose** - monosaccharide with 5 carbon atoms

**hexose** - monosaccharide with 6 carbon atoms

**aldohexose** - 6-carbon aldehyde (e.g., glucose)

**aldopentose** - 5-carbon aldehyde (e.g., ribose)

**ketohexose** - 6-carbon hexose (e.g., fructose)

**Structure, Forms and Isomers:**

**Monosaccharide e.g glucose**

D-glucose is an aldohexose with the formula \((\text{C-H}_2\text{O})_6\). The red atoms highlight the aldehyde group, and the blue atoms highlight the asymmetric center furthest from the aldehyde; because this -OH is on the right of the Fischer projection, this is a D sugar. Glucose can exist in both a straight-chain and ring form. The aldehyde or ketone group of a straight-chain monosaccharide will react reversibly with a hydroxyl group on a different carbon atom to form a hemiacetal or hemiketal, forming a heterocyclic ring with an oxygen bridge between two carbon atoms. Rings with five and six atoms are called furanose and pyranose forms, respectively, and exist in equilibrium with the straight-chain form.

**Disaccharides e.g sucrose**
Sucrose, also known as table sugar, is a common disaccharide. It is composed of two monosaccharides: D-glucose (left) and D-fructose (right).

**Oligosaccharides and polysaccharides**

Amylose is a linear polymer of glucose mainly linked with α(1→4) bonds. It can be made of several thousands of glucose units. It is one of the two components of starch, the other being amyllopectin.

The α and β anomers of glucose. Note the position of the hydroxyl group (red or green) on the anomeric carbon relative to the CH₂OH group bound to carbon 5: they are either on the opposite sides (α), or the same side (β).

**Starch Gelatinization and Pasting, Gelation, and Uglification**

Starch granules contain both linear amylose and branched amyllopectin. The following illustrations take place when heat is applied to starch.

- (1) Raw, uncooked starch granules heated in water
(2) Swelling is evident

(3) Notice loss of amylose from the granules

(4) Some granules have collapsed

Gelatinization and pasting are complete

After heating:
(5) Now we start to cool.

(6) This is a starch gel

(7) 

(8) WATER of SYNERESIS that has been squeezed out of the gel structure. The texture gets very ugly when this happens.

Timeline

gelatinization       gelation       uglification

(9) Ugly texture Syneresis
Carbohydrate metabolism

Catabolism is the metabolic reaction cells undergo to extract energy. There are two major metabolic pathways of monosaccharide catabolism: glycolysis and the citric acid cycle.

Glycolysis is the name given to the series of biochemical reactions in which glucose is converted into pyruvate. This carbohydrate catabolism takes place in the cytoplasm of cells. Several reactions take place, with products that are vital to the functioning of cell as shown below.

B. LIPIDS

What Is a Lipid?

A lipid is a fat-soluble molecule. To put it another way, lipids are insoluble in water but soluble in at least one organic solvent. The other major classes of organic compounds (nucleic acids, proteins, and carbohydrates) are much more soluble in water than in an organic solvent. Lipids do not share a common molecule structure.
Examples of Common Lipids

There are many different types of lipids. Examples of common lipids include butter, vegetable oil, cholesterol and other steroids, waxes, phospholipids, and fat-soluble vitamins. The common characteristic of all of these compounds is that they are essentially insoluble in water yet soluble in one or more organic solvents.

What Are the Functions of Lipids?

Lipids are used by organisms for energy storage, as a signaling molecule (e.g., steroid hormones), and as a structural component of cell membranes.

Lipid Structure

Although there is no single common structure for lipids, the most commonly occurring class of lipids are triglycerides, which are fats and oils. Triglycerides have a glycerol backbone bonded to three fatty acids. If the three fatty acids are identical then the triglyceride is termed a simple triglyceride. Otherwise, the triglyceride is called a mixed triglyceride.

The second most abundant class of lipids are the phospholipids, which are found in animal and plant cell membranes. Phospholipids also contain glycerol and fatty acids, plus the contain phosphoric acid and a low-molecular-weight alcohol. Common phospholipids include lecithins and cephalins.

\[
\begin{align*}
\text{H}_2\text{C} & \text{O} \text{R}_1 \\
\text{H} & \text{C} \text{O} \text{R}_2 \\
\text{H}_2\text{C} & \text{O} \text{R}_3 
\end{align*}
\]

This is the general chemical structure of triacylglycerol, a triglyceride and the most abundant form of lipid. Triglycerides result from the reaction between glycerol and fatty acids.

Types of fatty acids

Fatty acids can be saturated and unsaturated, depending on double bonds. They differ in length as well.

Long and short fatty acids

In addition to saturation, fatty acids have different lengths, often categorized as short, medium, or long.

- Short-chain fatty acids (SCFA) are fatty acids with aliphatic tails of fewer than six carbons.
- Medium-chain fatty acids (MCFA) are fatty acids with aliphatic tails of 6–12. carbons, which can form medium-chain triglycerides.
- Long-chain fatty acids (LCFA) are fatty acids with aliphatic tails longer than 12 carbons.
- Very-Long-chain fatty acids (VLCFA) are fatty acids with aliphatic tails longer than 22 carbons

### Unsaturated fatty acids

Comparison of the *trans* isomer (top) Elaidic acid and the *cis*-isomer oleic acid.

Unsaturated fatty acids resemble saturated fatty acids, except that the chain has one or more double-bonds between carbon atoms. The two carbon atoms in the chain that are bound next to either side of the double bond can occur in a *cis* or *trans* configuration.

A *cis* configuration means that adjacent hydrogen atoms are on the same side of the double bond. The rigidity of the double bond freezes its conformation and, in the case of the *cis* isomer, causes the chain to bend and restricts the conformational freedom of the fatty acid. The more double bonds the chain has in the *cis* configuration, the less flexibility it has. When a chain has many *cis* bonds, it becomes quite curved in its most accessible conformations. For example, oleic acid, with one double bond, has a "kink" in it, whereas linoleic acid, with two double bonds, has a more pronounced bend. Alpha-linolenic acid, with three double bonds, favors a hooked shape. The effect of this is that, in restricted environments, such as when fatty acids are part of a phospholipid in a lipid bilayer, or triglycerides in lipid droplets, cis bonds limit the ability of fatty acids to be closely packed, and therefore could affect the melting temperature of the membrane or of the fat.

A *trans* configuration, by contrast, means that the next two hydrogen atoms are bound to *opposite* sides of the double bond. As a result, they do not cause the chain to bend much, and their shape is similar to straight saturated fatty acids.

In most naturally occurring unsaturated fatty acids, each double bond has three *n* carbon atoms after it, for some *n*, and all are *cis* bonds. Most fatty acids in the *trans* configuration (trans fats) are not found in nature and are the result of human processing (e.g., hydrogenation).

The differences in geometry between the various types of unsaturated fatty acids, as well as between saturated and unsaturated fatty acids, play an important role in biological processes, and in the construction of biological structures (such as cell membranes).
### Examples of Unsaturated Fatty Acids

<table>
<thead>
<tr>
<th>Common name</th>
<th>Chemical structure</th>
<th>C:D</th>
<th>n-x</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristoleic acid</td>
<td>CH₃(CH₂)₇CH=CH(CH₂)₇COOH</td>
<td>14:1</td>
<td>n-5</td>
</tr>
<tr>
<td>Palmitoleic acid</td>
<td>CH₃(CH₂)₁₄CH=CH(CH₂)₇COOH</td>
<td>16:1</td>
<td>n-7</td>
</tr>
<tr>
<td>Sapienic acid</td>
<td>CH₃(CH₂)₈CH=CH(CH₂)₇COOH</td>
<td>16:1</td>
<td>n-1</td>
</tr>
<tr>
<td>Oleic acid</td>
<td>CH₃(CH₂)₁₄CH=CH(CH₂)₇COOH</td>
<td>18:1</td>
<td>n-9</td>
</tr>
<tr>
<td>Elaidic acid</td>
<td>CH₃(CH₂)₁₄CH=CH(CH₂)₇COOH</td>
<td>18:1</td>
<td>n-9</td>
</tr>
<tr>
<td>Vaccenic acid</td>
<td>CH₃(CH₂)₁₄CH=CH(CH₂)₇COOH</td>
<td>18:1</td>
<td>n-7</td>
</tr>
<tr>
<td>Linoleic acid</td>
<td>CH₃(CH₂)₆CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>18:2</td>
<td>n-6</td>
</tr>
<tr>
<td>Linoelaidic acid</td>
<td>CH₃(CH₂)₆CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>18:2</td>
<td>n-6</td>
</tr>
<tr>
<td>α-Linolenic acid</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₇COOH</td>
<td>18:3</td>
<td>n-3</td>
</tr>
<tr>
<td>Arachidonic acid</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₉COOH</td>
<td>20:4</td>
<td>n-6</td>
</tr>
<tr>
<td>Eicosapentaenoic acid</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₃COOH</td>
<td>20:5</td>
<td>n-3</td>
</tr>
<tr>
<td>Erucic acid</td>
<td>CH₃(CH₂)₁₅CH=CH(CH₂)₁₁COOH</td>
<td>22:1</td>
<td>n-9</td>
</tr>
<tr>
<td>Docosahexaenoic acid</td>
<td>CH₃CH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH=CHCH₂CH=CH(CH₂)₉COOH</td>
<td>22:6</td>
<td>n-3</td>
</tr>
</tbody>
</table>

### Essential fatty acids

Fatty acids that are required by the human body but cannot be made in sufficient quantity from other substrates and therefore must be obtained from food and are called essential fatty acids. There are two series of essential fatty acids: one has a double bond three carbon atoms removed from the methyl end; the other has a double bond six carbon atoms removed from the methyl end. Humans lack the ability to introduce double bonds in fatty acids beyond carbons 9 and 10, as counted from the carboxylic acid side., Two essential fatty acids are linoleic acid (LA) and alpha-linolenic acid (ALA). They are widely distributed in plant oils. The human body has a limited ability to convert ALA into the longer-chain n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which can also be obtained from fish.

### Saturated fatty acids

Saturated fatty acids are long-chain carboxylic acids that usually have between 12 and 24 carbon atoms and have no double bonds. Thus, saturated fatty acids are saturated with hydrogen (since
double bonds reduce the number of hydrogens on each carbon). Because saturated fatty acids have only single bonds, each carbon atom within the chain has 2 hydrogen atoms (except for the omega carbon at the end that has 3 hydrogens).

### Examples of Saturated Fatty Acids

<table>
<thead>
<tr>
<th>Common name</th>
<th>Chemical structure</th>
<th>C.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lauric acid</td>
<td>CH₃(CH₂)₁₀COOH</td>
<td>12:0</td>
</tr>
<tr>
<td>Myristic acid</td>
<td>CH₃(CH₂)₁₂COOH</td>
<td>14:0</td>
</tr>
<tr>
<td>Palmitic acid</td>
<td>CH₃(CH₂)₁₄COOH</td>
<td>16:0</td>
</tr>
<tr>
<td>Stearic acid</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>18:0</td>
</tr>
<tr>
<td>Arachidic acid</td>
<td>CH₃(CH₂)₁₈COOH</td>
<td>20:0</td>
</tr>
<tr>
<td>Behenic acid</td>
<td>CH₃(CH₂)₂₀COOH</td>
<td>22:0</td>
</tr>
<tr>
<td>Lignoceric acid</td>
<td>CH₃(CH₂)₂₂COOH</td>
<td>24:0</td>
</tr>
<tr>
<td>Cerotic acid</td>
<td>CH₃(CH₂)₂₄COOH</td>
<td>26:0</td>
</tr>
</tbody>
</table>

### C. Protein

**Proteins** are biochemical compounds consisting of one or more polypeptides typically folded into a globular or fibrous form in a biologically functional way. A polypeptide is a single linear polymer chain of amino acids bonded together by peptide bonds between the carboxyl and amino groups of adjacent amino acid residues. The sequence of amino acids in a protein is defined by the sequence of a gene, which is encoded in the genetic code. In general, the genetic code specifies 20 standard amino acids; however, in certain organisms the genetic code can include selenocysteine—and in certain archaea—pyrrolysine. Shortly after or even during synthesis, the residues in a protein are often chemically modified by post-translational modification, which alters the physical and chemical properties, folding, stability, activity, and ultimately, the function of the proteins. Sometimes proteins have non-peptide groups attached, which can be called prosthetic groups or cofactors. Proteins can also work together to achieve a particular function, and they often associate to form stable complexes.

### Protein Structure

Most proteins fold into unique 3-dimensional structures. The shape into which a protein naturally folds is known as its native conformation. Although many proteins can fold unassisted, simply through the chemical properties of their amino acids, others require the aid of molecular chaperones to fold into their native states. Biochemists often refer to four distinct aspects of a protein's structure:

- **Primary structure:** the amino acid sequence.
- **Secondary structure**: regularly repeating local structures stabilized by hydrogen bonds. The most common examples are the alpha helix, beta sheet and turns. Because secondary structures are local, many regions of different secondary structure can be present in the same protein molecule.

- **Tertiary structure**: the overall shape of a single protein molecule; the spatial relationship of the secondary structures to one another. Tertiary structure is generally stabilized by nonlocal interactions, most commonly the formation of a hydrophobic core, but also through salt bridges, hydrogen bonds, disulfide bonds, and even post-translational modifications. The term "tertiary structure" is often used as synonymous with the term fold. The tertiary structure is what controls the basic function of the protein.

- **Quaternary structure**: the structure formed by several protein molecules (polypeptide chains), usually called *protein subunits* in this context, which function as a single protein complex.

**Amino Acids**

Amino acids are molecules containing an amine group, a carboxylic acid group and a side-chain that varies between different amino acids. The key elements of an amino acid are carbon, hydrogen, oxygen, and nitrogen. They are particularly important in biochemistry, where the term usually refers to *alpha-amino acids*. 

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**Peptide bond formation**

The condensation of two amino acids to form a peptide bond. As both the amine and carboxylic acid groups of amino acids can react to form amide bonds, one amino acid molecule can react with another and become joined through an amide linkage. This polymerization of amino acids is what creates proteins.

**D. Enzymes**

*Enzymes* are proteins that catalyze (i.e., increase or decrease the rates of) chemical reactions. In enzymatic reactions, the molecules at the beginning of the process are called substrates, and they are converted into different molecules, called the products. Almost all processes in a biological cell need enzymes to occur at significant rates.

"Lock and key" model of enzymes

Enzymes are very specific because both the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another. This is often referred to as "the lock and key" model.
Mechanism of Enzyme actions

Enzymes can act in several ways, all of which lower $\Delta G^\ddagger$:

- Lowering the activation energy $\Delta G^\ddagger$ by creating an environment in which the transition state is stabilized (e.g. straining the shape of a substrate—by binding the transition-state conformation of the substrate/product molecules, the enzyme distorts the bound substrate(s) into their transition state form, thereby reducing the amount of energy required to complete the transition).
- Lowering the energy of the transition state, but without distorting the substrate, by creating an environment with the opposite charge distribution to that of the transition state.
- Providing an alternative pathway. For example, temporarily reacting with the substrate to form an intermediate ES complex, which would be impossible in the absence of the enzyme.
- Reducing the reaction entropy change by bringing substrates together in the correct orientation to react. Considering $\Delta H^\ddagger$ alone overlooks this effect.
- Increases in temperatures speed up reactions. Thus, temperature increases help the enzyme function and develop the end product even faster. However, if heated too much, the enzyme’s shape deteriorates and the enzyme becomes denatured. Some enzymes like thermolabile enzymes work best at low temperatures.

Interestingly, this entropic effect involves destabilization of the ground state, and its contribution to catalysis is relatively small.

Cofactors

Some enzymes do not need any additional components to show full activity. However, others require non-protein molecules called cofactors to be bound for activity. Cofactors can be either inorganic (e.g., metal ions and iron-sulfur clusters) or organic compounds (e.g., flavin and heme). Organic cofactors can be either prosthetic groups, which are tightly bound to an enzyme, or coenzymes, which are released from the enzyme’s active site during the reaction. Coenzymes include NADH, NADPH and adenosine triphosphate. These molecules transfer chemical groups between enzymes.

An example of an enzyme that contains a cofactor is carbonic anhydrase, and is shown in the ribbon diagram above with a zinc cofactor bound as part of its active site.
Enzyme Thermodynamics

The energies of the stages of a chemical reaction. Substrates need a lot of energy to reach a transition state, which then decays into products. The enzyme stabilizes the transition state, reducing the energy needed to form products.

As all catalysts, enzymes do not alter the position of the chemical equilibrium of the reaction. Usually, in the presence of an enzyme, the reaction runs in the same direction as it would without the enzyme, just more quickly. However, in the absence of the enzyme, other possible uncatalyzed, "spontaneous" reactions might lead to different products, because in those conditions this different product is formed faster.

Furthermore, enzymes can couple two or more reactions, so that a thermodynamically favorable reaction can be used to "drive" a thermodynamically unfavorable one. For example, the hydrolysis of ATP is often used to drive other chemical reactions.

Enzymes catalyze the forward and backward reactions equally. They do not alter the equilibrium itself, but only the speed at which it is reached. For example, carbonic anhydrase catalyzes its reaction in either direction depending on the concentration of its reactants.

\[
\text{CO}_2 + \text{H}_2\text{O} \xrightarrow{\text{Carbonic anhydrase}} \text{H}_2\text{CO}_3 \quad \text{(in tissues; high CO}_2\text{ concentration)}
\]

\[
\text{H}_2\text{CO}_3 \xrightarrow{\text{Carbonic anhydrase}} \text{CO}_2 + \text{H}_2\text{O} \quad \text{(in lungs; low CO}_2\text{ concentration)}
\]

Nevertheless, if the equilibrium is greatly displaced in one direction, that is, in a very exergonic reaction, the reaction is *effectively* irreversible. Under these conditions the enzyme will, in fact, only catalyze the reaction in the thermodynamically allowed direction.
Enzyme Kinetics

Mechanism for a single substrate enzyme catalyzed reaction. The enzyme (E) binds a substrate (S) and produces a product (P).

Enzyme kinetics is the investigation of how enzymes bind substrates and turn them into products. The rate data used in kinetic analyses are obtained from enzyme assays.

The enzyme reactions are in two stages. In the first, the substrate binds reversibly to the enzyme, forming the enzyme-substrate complex. This is sometimes called the Michaelis complex. The enzyme then catalyzes the chemical step in the reaction and releases the product.

Saturation curve for an enzyme reaction showing the relation between the substrate concentration (S) and rate (v)

Enzymes can catalyze up to several million reactions per second. Enzyme rates depend on solution conditions and substrate concentration. Conditions that denature the protein abolish enzyme activity, such as high temperatures, extremes of pH or high salt concentrations, while raising substrate concentration tends to increase activity. To find the maximum speed of an enzymatic reaction, the substrate concentration is increased until a constant rate of product formation is seen. This is shown in the saturation curve on the right. Saturation happens because, as substrate concentration increases, more and more of the free enzyme is converted into the substrate-bound ES form. At the maximum reaction rate (V$_{\text{max}}$) of the enzyme, all the enzyme active sites are bound to substrate, and the amount of ES complex is the same as the total amount of enzyme. However, V$_{\text{max}}$ is only one kinetic constant of enzymes. The amount of substrate needed to achieve a given rate of reaction is also important. This is given by the Michaelis-Menten constant (K$_{\text{m}}$), which is the
substrate concentration required for an enzyme to reach one-half its maximum reaction rate. Each enzyme has a characteristic $K_m$ for a given substrate, and this can show how tight the binding of the substrate is to the enzyme. Another useful constant is $k_{cat}$, which is the number of substrate molecules handled by one active site per second.

E. Vitamins
A *vitamin* is an organic compound required as a nutrient in tiny amounts by an organism.[1] In other words, an organic chemical compound (or related set of compounds) is called a vitamin when it cannot be synthesized in sufficient quantities by an organism, and must be obtained from the diet.

Types of vitamin and their structures

The types of vitamins are Vitamin C, Vitamin B1 (Thiamin), Niacin, Riboflavin, Vitamin B6, Folic Acid (Folacin), Vitamin B12 (Cobalamin), Vitamin A, Vitamin D, Vitamin E, Vitamin K, Biotin, Pantothenic Acid.

*Vitamin A*:

![Vitamin A structure]

*Vitamin B*
A vitamin that can be dissolved in water. It is one of the B complex vitamins. Vitamin B6 helps the body by building protein, making antibodies and making the red blood cells. There are actually eight separate vitamins in the B family: thiamin (vitamin B1), riboflavin (vitamin B2), niacin, vitamin B6, folate, vitamin B12, biotin, and pantothenic. B vitamins increase energy levels, regulate metabolism, and help create new red blood cells. Foods with high B levels include meats, fish, liver, dark/leafy vegetables, whole-grains, and fortified products.
Biotin:
The B vitamin complex includes vitamins B1, niacin, B6, B12, folate, biotin, and pantothenic acid. Biotin helps the body use protein, fat and carbohydrate from foods for energy. It helps the body produce energy in the cells. Pantothenic acid is needed to make cholesterol, bile, some fats, red blood cells, hormones and nerve regulators.

Folic Acid:
Folacin is also known as folic acid and folate. It is a water-soluble vitamin and is one of 8 members of the B complex including vitamins B1, B2, B3, B6, B12, biotin and pantothenic acid. Fortified grain products such as commercial breads, cereals and pastas are good sources of folacin.
Folate assists prevention of neural tube defects (spina bifida) in fetuses before birth and involvement in production of neurotransmitters, such as serotonin, that regulate mood, sleep, and appetite.

**Niacin**
Niacin is one of the eight B complex vitamins including vitamins B1, B2, B6, B12, folate, biotin, and pantothenic acid. Niacin works closely with vitamin B1, B2, B6, pantothenic acid, and biotin to break the carbohydrates, fats, and proteins in food down into energy. Without niacin, the body would not be able to convert the food we eat into energy. Niacin has been used with some success to treat people with high cholesterol levels.

**Pantothenic Acid:**
Pantothenic Acid and biotin are water-soluble vitamins.

**Riboflavin:**
Riboflavin is also called Vitamin B2. Milk products supply about half of the riboflavin that people get and unlike other vitamins, riboflavin is not destroyed by cooking. Vegetarians may have riboflavin deficiencies. Children who do not get enough riboflavin may have poor growth. Vitamin supplements usually reverse symptoms within days to a few weeks.

**Thiamine:**
Thiamine, also known as Vitamin B1 and because thiamine is water-soluble, any extra is passed out of the body in the urine. Thiamine is needed each day to maintain health. Thiamine can be lost in cooking due to heat. A well balanced diet based on the New Food Pyramid should provide enough thiamine daily.

**Vitamin E** is involved with immune system, DNA, and metabolism maintenance. As an antioxidant, research indicates that it may have a positive effect against cardiovascular disease and cancer. Vitamin E can be found in nuts, particularly almonds, wheat germ oil, vegetable oil, green/leafy vegetables, and enriched cereals.

**Vitamin K:**
While involved in protection against osteoporosis, skin wounds, and possibly cancer, Vitamin K significantly helps blood to clot after an injury. Also found in a variety of foods, especially vegetables, K most often forms from intestine bacteria in the body.

**Vitamin K is in foods:** collards, kale, and other green leafy vegetables cabbage family including broccoli, cauliflower and Brussels, sprouts, egg yolk, some fruits, liver, cheese, milk.

**Course requirements:**
- **CAT:** 30% (Test 20% & assignment 10%)
- **Exam:** 70%
- **70% Class attendance compulsory**
General Nutrition Concepts

- Influences of Nutrition
  - Health
  - Appearance
  - Behavior
  - Mood
- Role of Nutrients in Diet
  - Growth and development
  - Provide energy
  - Regulate metabolism

Classes of Nutrients

- Carbohydrates
- Proteins
- Fats
- Vitamins
- Minerals
- Water

Types of Carbohydrates (2 types)

- Simple
  - pop, candy, sweets, fruit
  - individual glucose or fructose molecules
- Complex
  - pasta, rice, breads, potatoes
  - Chains of glucose molecules

Figure 1: different types of carbohydrates
Low Carb Mania

- Proponents of low carb diets blame carbohydrates on the obesity epidemic but this is not well supported by research.
- The quality of carbohydrates is the real issue and it is still wise to consume quality whole grains with adequate fiber.

Types of Protein

- Sources of Protein
  - Animal (complete)
    - meats, dairy
  - Vegetable (incomplete)
    - beans, nuts, legumes, grains
- Types of Amino Acids
  - Nonessential (14) – can be made by body
  - Essential (8) – must be made by body

Protein Requirements

- RDA average = 0.8 g/kg/day
- RDA athlete = 1.2-1.6 g/kg/day

High levels of protein intake above 2 g/kg/day can be harmful to the body

Types of Fats

- Saturated
  - Animal sources
  - Solid at room temperature
- Unsaturated (poly- or mono-)

Recommendations for Fat Consumption

• Dietary Fat Recommendations
  – Less than 30% of calories in diet from fat
  – Less than 1/3 of dietary fat should be saturated

• Ways to Decrease Intake of Fat
  – Minimize "fast" foods
  – Minimize processed foods
  – Use better cuts of meats
  – Use low fat alternatives
  – Decrease use of condiments
  – Eat lower fat snacks
  – Choose foods with “artificial fats”

Vitamins

• Organic substances that regulate numerous and diverse physiological processes in the body
• Do not contain calories
• Two types
  – Fat soluble
  – Water soluble

Vitamin Guidelines

• A balanced diet containing recommended servings of carbohydrates, fats and proteins will meet the RDA standards
• Extra servings of green and yellow vegetables may be beneficial
• Extra consumption of citrus and other fruits may be beneficial
Vitamin Supplementation?

- Not necessary if diet is healthy
- Multivitamins are safe (100% RDA)
- Not all vitamins are “pure”
- Can be toxic at high doses

Minerals

- Inorganic elements found in food that are essential to life processes
- About 25 are essential
- Classified as major or trace minerals
- RDA’s have only been determined for 7 minerals

Mineral Guidelines

- A diet containing recommended servings of carbohydrates, fats and proteins will meet the RDA standards
- Extra servings of green and yellow vegetables may be beneficial
- Dietary supplementation of Calcium is beneficial for post-menopausal women
- Salt should be limited in the diet

Populations Who May Benefit from Supplementation

- Pregnant/lactating women
- Alcoholics
- Elderly
- Women with severe menstrual losses
- Individuals on VLCD’s
- Strict vegetarians
- Individuals taking medications or with diseases which inhibit nutrient absorption

Water
- Vital to life
- Drink at least 8 glasses a day

**Follow principles in the Food Guide Pyramid**

- Eat regular meals (including breakfast)
- Eat foods from all food groups and according to the food pyramid
- Limit processed foods
- Get adequate amounts of vitamins and minerals
- Drink plenty of water and limit alcohol and caffeine

**Additional Details on Nutrition**

**Nutrition Analysis**

- Purpose: Compare quality of “favorite diet” with your ideal “healthy diet”
- Procedure: Select foods from food list (Appendix D or other diet tables) and calculate calories from carbohydrates, fats and proteins.

<table>
<thead>
<tr>
<th>Foods</th>
<th>Calories</th>
<th>% of total calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>350</td>
<td>13.7</td>
</tr>
<tr>
<td>Fat</td>
<td>800</td>
<td>31.4</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>1400</td>
<td>54.9</td>
</tr>
<tr>
<td>Total</td>
<td>2550</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Selecting Nutritious Foods**

- Purpose: Evaluate the nutritional quality of your diet
- Procedure: Record foods consumed for two days on the Daily Diet Record. Calculate calorie intake from list in Appendix C
- Implications: Rate the quality of the diet according to the Rating Scale.
Fiber

- Soluble - decreases cholesterol levels
  - found in oat bran, fruits and veggies
- Insoluble - reduces risk of colon cancer
  - found in wheat bran and grains

**Recommendation: 25-40g per day**

Ways to Get More Fiber

- Eat more fruits and vegetables
- Eat whole grain foods

![Different types of food sources](image)

Figure 3: different types of food sources

### Table 2: Composition of oils (%)

<table>
<thead>
<tr>
<th>Type</th>
<th>Sat</th>
<th>Pol</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>safflower</td>
<td>9</td>
<td>75</td>
<td>16</td>
</tr>
<tr>
<td>sunflower</td>
<td>10</td>
<td>66</td>
<td>24</td>
</tr>
<tr>
<td>corn</td>
<td>13</td>
<td>59</td>
<td>28</td>
</tr>
<tr>
<td>soybeans</td>
<td>14</td>
<td>58</td>
<td>28</td>
</tr>
<tr>
<td>sesame</td>
<td>14</td>
<td>42</td>
<td>44</td>
</tr>
<tr>
<td>peanut</td>
<td>17</td>
<td>32</td>
<td>51</td>
</tr>
<tr>
<td>palm</td>
<td>40</td>
<td>9</td>
<td>42</td>
</tr>
<tr>
<td>olive</td>
<td>14</td>
<td>8</td>
<td>78</td>
</tr>
<tr>
<td>canola</td>
<td>7</td>
<td>35</td>
<td>58</td>
</tr>
</tbody>
</table>

Where,

Sat are saturated, Poly(Polyunsaturated) and Mono(monounsaturated)
Hydrogenation Process

Figure 4: Hydrogenation process flow diagram

Fat Soluble Vitamins

- Consist of Vitamins A, D, E, and K
- Absorbed at the small intestine in the presence of bile (a fatty substance)
- Overdoses can be toxic (A and D)

Water Soluble Vitamins

- Consist of B complex and vitamin C
- Excesses will be excreted in the urine, however, B-6 and Niacin can be toxic when ingested in unusually large amounts

Water Soluble Vitamins

- B-1 (thiamine)
- B-2 (riboflavin)
- B-6 (pyridoxine)
- B-12 (cobalamin)
• Niacin (nicotinic acid)
• Pantothenic Acid
• Folic Acid (folacin)
• Biotin
• C

Antioxidant All-Stars

• Broccoli
• Cantaloupe
• Carrot
• Kale
• Mango
• Pumpkin
• Red Pepper
• Spinach
• Strawberries
• Sweet potato

Minerals with established RDA guidelines

• Calcium
• Phosphorus
• Iodine
• Iron
• Magnesium
• Zinc
• Selenium

Calcium
• Important for preventing osteoporosis
• RDA = 800-1000 mg/day
• Found in dairy products and vegetables

High protein diets leach calcium from bones and promote osteoporosis

Iron

• Important component of hemoglobin
• Iron deficiency is known as anemia (Symptoms: shortness of breath, fatigue)

Functions of Water

• Comprises about 60% of body weight
• Chief component of blood plasma
• Aids in temperature regulation
• Lubricates joints
• Shock absorber in eyes, spinal cord, and amniotic sac (during pregnancy)
• Active participant in many chemical reactions

Caloric Content of Foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Caloric Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>4 cal/g</td>
</tr>
<tr>
<td>Protein</td>
<td>4 cal/g</td>
</tr>
<tr>
<td>Fats</td>
<td>9 cal/g</td>
</tr>
<tr>
<td>Alcohol</td>
<td>7 cal/g</td>
</tr>
</tbody>
</table>

Calorie Calculation (Example)

• Heather consumes 2000 calories per day and wishes to obtain 20% of her calories from fat:

\[2000 \text{ calories} \times 20\% = 400 \text{ calories from fat per day}\]
400 calories from fat = 44 grams of fat/day

**What is Baloney?**

- 80% "fat free"
- 52 calories / slice
- 4 grams fat / slice

Calories from fat = 4 g/slice X 9 cal/g = 36 calories

Percent of calories from fat = 36 cal / 52 cal total = 69%

**What about Sliced Turkey?**

- 98% "fat free"
- 30 calories / slice
- 1 gram fat / slice

Calories from fat = 1 g/slice X 9 cal/g = 9 calories

Percent of calories from fat = 9 cal / 30 cal total = 30%

**Fat Substitutes**

- Olestra
- Simplesse
Figure 5: The Food Pyramid
References

- http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&ved=0CEsQFjAD&url=http%3A%2F%2Fjournals.cambridge.org%2Farticle_S0029665102000058&ei=mhTzUuvjL8GSrgf88YCA&w&usg=AFQjCNE4oS6991Ff1MmZli pkXTXmpAlDgQ&sig2=QcmXjDu4bUzO9bs8cvXyg
- http://www.soilandhealth.org/06clipfile/nutritional%20quality%20of%20organically-grown%20food.html
FOOD PROCESSING 2

Module- 34

Lec- 34

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Introduction

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 foods and 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-

Physical Characteristics

1. Shape
2. Size
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
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

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.
Raw Material Properties

The main raw material properties of importance to the processor are

- Geometry,
- Colour,
- Texture,
- Flavour,
- Functional 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.
For example,

- 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.

**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.

**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.

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.

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.
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.

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.

Damage to Raw Materials:

• 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.

**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.

**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:
    - high levels of lauric acid to improve emulsification properties for use in confectionery, coatings or low fat dairy products,
    - high levels of stearate as an alternative to hydrogenation in manufacture of margarine,
    - 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.

Storage of Raw Materials

Storage of food is necessary at all points of the food chain from raw materials, through manufacture, distribution, retailers and final purchasers. Today’s consumers expect a much greater variety of products, including nonlocal materials, to be available throughout the year. Effective transportation and storage systems for raw materials are essential to meet this need.

Storage of materials whose supply or demand fluctuate in a predictable manner, especially seasonal produce, is necessary to increase availability. It is essential that processors maintain stocks of raw materials, therefore storage is necessary to buffer demand.

However, storage of raw materials is expensive for two reasons: firstly, stored goods have been paid for and may therefore tie up quantities of company money and, secondly, warehousing and storage space are expensive.

All raw materials deteriorate during storage. The quantities of raw materials held in store and the times of storage vary widely for different cases, depending on the above considerations. The ‘just in time’ approaches used in other industries are less common in food processing.

The primary objective is to maintain the best possible quality during storage, and hence avoid spoilage during the storage period. Spoilage arises through three mechanisms:

- living organisms such as vermin, insects, fungi and bacteria: these may feed on the food and contaminate it;
- biochemical activity within the food leading to quality reduction, such as: respiration in fruits and vegetables, staling of baked products, enzymic browning reactions, rancidity development in fatty food;
- physical processes, including damage due to pressure or poor handling, physical changes such as dehydration or crystallisation.
The main factors which govern the quality of stored foods are temperature, moisture/humidity and atmospheric composition. Different raw materials provide very different challenges.

Fruits and vegetables remain as living tissues until they are processed and the main aim is to reduce respiration rate without tissue damage. Storage times vary widely between types. Young tissues such as shoots, green peas and immature fruits have high respiration rates and shorter storage periods, while mature fruits and roots and storage organs such as bulbs and tubers, e.g. onions, potatoes, sugar beets, respire much more slowly and hence have longer storage periods.

Many fruits (including bananas, apples, tomatoes and mangoes) display a sharp increase in respiration rate during ripening, just before the point of optimum ripening, known as the ‘climacteric’. The onset of the climacteric is associated with the production of high levels of ethylene, which is believed to stimulate the ripening process. Climacteric fruit can be harvested unripe and ripened artificially at a later time.

- It is vital to maintain careful temperature control during storage or the fruit will rapidly over-ripen. Nonclimacteric fruits, e.g. citrus fruit, pineapples, strawberries, and vegetables do not display this behaviour and generally do not ripen after harvest. Quality is therefore optimal at harvest, and the task is to preserve quality during storage.

**Typical Storage Conditions**

**Table 1 Storage periods of some fruits and vegetables under typical storage conditions.**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Temperature (°C)</th>
<th>Humidity (%)</th>
<th>Storage period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>0</td>
<td>70</td>
<td>6–8 months</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>0</td>
<td>90–95</td>
<td>5–7 days</td>
</tr>
<tr>
<td>Green bananas</td>
<td>13–15</td>
<td>85–90</td>
<td>10–30 days</td>
</tr>
<tr>
<td>Immature potatoes</td>
<td>4–5</td>
<td>90–95</td>
<td>3–8 weeks</td>
</tr>
<tr>
<td>Mature potatoes</td>
<td>4–5</td>
<td>90–95</td>
<td>4–9 months</td>
</tr>
<tr>
<td>Onions</td>
<td>0 to 0</td>
<td>70–80</td>
<td>6–8 months</td>
</tr>
<tr>
<td>Oranges</td>
<td>2–7</td>
<td>90</td>
<td>1–4 months</td>
</tr>
<tr>
<td>Mangoes</td>
<td>5.5–14</td>
<td>90</td>
<td>2–7 weeks</td>
</tr>
<tr>
<td>Apples</td>
<td>0 to 4</td>
<td>90–95</td>
<td>1–8 months</td>
</tr>
<tr>
<td>French beans</td>
<td>7–8</td>
<td>95–100</td>
<td>1–2 weeks</td>
</tr>
</tbody>
</table>
• With meat storage the overriding problem is growth of spoilage bacteria, while avoiding oxidative rancidity. Cereals must be dried before storage to avoid germination and mould growth and subsequently must be stored under conditions which prevent infestation with rodents, birds, insects or moulds.
• Hence, very different storage conditions may be employed for different raw materials. The main methods employed in raw material storage are the control of temperature, humidity and composition of atmosphere.

**Temperature**

• The rate of biochemical reactions is related to temperature, such that lower storage temperatures lead to slower degradation of foods by biochemical spoilage, as well as reduced growth of bacteria and fungi. There may also be limited bacteriocidal effects at very low temperatures. Typical $Q_{10}$ values for spoilage reactions are approximately 2, implying that spoilage rates would double for each $10\,^\circ C$ rise, or conversely that shelflife would double for each $10\,^\circ C$ reduction. This is an oversimplification, as $Q_{10}$ may change with temperature. Most insect activity is inhibited below $4\,^\circ C$, although insects and their eggs can survive long exposure to these temperatures. In fact, grain and flour mites can remain active and even breed at $0\,^\circ C$.
• The use of refrigerated storage is limited by the sensitivity of materials to low temperatures. The freezing point is a limiting factor for many raw materials, as the tissues will become disrupted on thawing. Other foods may be subject to problems at temperatures above freezing. Fruits and vegetables may display physiological problems that limit their storage temperatures, probably as a result of metabolic imbalance leading to a build up of undesirable chemical species in the tissues. Some types of apples are subject to internal browning below $3\,^\circ C$, while bananas become brown when stored below $13\,^\circ C$ and many other tropical fruits display chill sensitivity. Less obvious biochemical problems may occur even where no visible damage occurs. For example,
storage temperature affects the starch/sugar balance in potatoes: in particular below 10°C a build up of sugar occurs, which is most undesirable for fried products.

- Temperature of storage is also limited by cost. Refrigerated storage is expensive, especially in hot countries. In practice, a balance must be struck incorporating cost, shelflife and risk of cold injury. Slower growing produce such as onions, garlic and potatoes can be successfully stored at ambient temperature and ventilated conditions in temperate climates.

- It is desirable to monitor temperature throughout raw material storage and distribution. Precooling to remove the ‘field heat’ is an effective strategy to reduce the period of high initial respiration rate in rapidly respiring produce prior to transportation and storage. For example, peas for freezing are harvested in the cool early morning and rushed to cold storage rooms within 2–3 h. Other produce, such as leafy vegetables (lettuce, celery, cabbage) or sweetcorn, may be cooled using water sprays or drench streams. Hydrocooling obviously reduces water loss.

**Humidity**

- If the humidity of the storage environment exceeds the equilibrium relative humidity (ERH) of the food, the food will gain moisture during storage, and *vice versa*. *Uptake of water during storage is associated with susceptibility to growth* of microorganisms, whilst water loss results in economic loss and more specific problems, such as cracking of seed coats of cereals, or skins of fruits and vegetables.

- Ideally, the humidity of the store would equal the ERH of the food so that moisture is neither gained nor lost, but in practice a compromise may be necessary. The water activity \(a_w\) of most fresh foods (e.g. fruit, vegetables, meat, fish, milk) is in the range 0.98–1.00, but they are frequently stored at a lower humidity. Some wilting of fruits or vegetable may be acceptable in preference to mould growth, while some surface drying of meat is preferable to bacterial slime. Packaging may be used to protect against water loss of raw materials during storage and transport.
Composition of Atmosphere

- Controlling the atmospheric composition during storage of many raw materials is beneficial. With some materials, the major aim is to maintain an oxygen-free atmosphere to prevent oxidation, e.g. coffee, baked goods, while in other cases adequate ventilation may be necessary to prevent anaerobic fermentation leading to off flavours. In living produce, atmosphere control allows the possibility of slowing down metabolic processes, hence retarding respiration, ripening, senescence and the development of disorders. The aim is to introduce N2 and remove O2, allowing a build up of CO2.
- Controlled atmosphere storage technique allows year-round distribution of apples and pears, where controlled atmospheres in combination with refrigeration can give shelflives up to 10 months, much greater than by chilling alone.
- The particular atmospheres are cultivar specific, but in the range 1–10% CO2, 2–13% O2 at 3°C for apples and 0°C for pears. Controlled atmospheres are also used during storage and transport of chill-sensitive crops, such as for transport of bananas, where an atmosphere of 3% O2 and 5% CO2 is effective in preventing premature ripening and the development of crown rot disease. Ethene (ethylene) removal is also vital during storage of climacteric fruit. With fresh meat, controlling the gaseous environment is useful in combination with chilling. The aim is to maintain the red colour by storage in high O2 concentrations, which shifts the equilibrium in favour of high concentrations of the bright red oxymyoglobin pigment. At the same time, high levels of CO2 are required to suppress the growth of aerobic bacteria.

Other Considerations

- Odours and taints can cause problems, especially in fatty foods such as meat and dairy products, as well as less obvious commodities such as citrus fruits, which have oil in the skins. Odours and taints may be derived from fuels or adhesives and printing materials, as well as other foods, e.g. spiced or smoked products. Packaging and other systems during storage and transport must protect against contamination.
• Light can lead to oxidation of fats in some raw materials, e.g. dairy products. In addition, light gives rise to solanine production and the development of green pigmentation in potatoes.
• Hence, storage and transport under dark conditions is essential.

Transportation of Raw Materials

• Food transportation is an essential link in the food chain. Raw materials, food ingredients, fresh produce and processed products are all transported on a local and global level, by land, sea and air. In the modern world, where consumers expect year-round supplies and nonlocal products, long distance transport of many foods has become commonplace and air transport may be necessary for perishable materials.
• Transportation of food is really an extension of storage: a refrigerated lorry is basically a cold store on wheels. However, transport also subjects the material to physical and mechanical stresses, and possibly rapid changes in temperature and humidity, which are not encountered during static storage. It is necessary to consider both the stresses imposed during the transport and those encountered during loading and unloading.
• In many situations, transport is multimodal. Air or sea transport would commonly involve at least one road trip before and one road trip after the main journey. There would also be time spent on the ground at the port or airport where the material could be exposed to wideranging temperatures and humidities, or bright sunlight, and unscheduled delays are always a possibility. During loading and unloading, the cargo may be broken into smaller units where more rapid heat penetration may occur.
• The major challenges during transportation are to maintain the quality of the food during transport, and to apply good logistics – in other words, to move the goods to the right place at the right time and in good condition.

Raw Material Cleaning
• All food raw materials are cleaned before processing. The purpose is obviously to remove contaminants, which range from innocuous to dangerous. It is important to note that removal of contaminants is essential for protection of process equipment as well as the final consumer. For example, it is essential to remove sand, stones or metallic particles from wheat prior to milling to avoid damaging the machinery.

The main contaminants are:

- unwanted parts of the plant, such as leaves, twigs, husks;
- soil, sand, stones and metallic particles from the growing area;
- insects and their eggs;
- animal excreta, hairs etc.;
- pesticides and fertilisers;
- mineral oil;
- microorganisms and their toxins.

• Cleaning is essentially separation in which some difference in physical properties of the contaminants and the food units is exploited.

• There are a number of cleaning methods available, classified into dry and wet methods, but a combination would usually be employed for any specific material.

• Selection of the appropriate cleaning regime depends on the material being cleaned, the level and type of contamination and the degree of decontamination required. In practice a balance must be struck between cleaning cost and product quality, and an ‘acceptable standard’ should be specified for the particular end use. Avoidance of product damage is an important contributing factor, especially for delicate materials such as soft fruit.

**Dry Cleaning Methods**

- The main dry cleaning methods are based on screens, aspiration or magnetic separations.
- Dry methods are generally less expensive than wet methods and the effluent is cheaper to dispose of, but they tend to be less effective in terms of cleaning efficiency. A major
problem is recontamination of the material with dust. Precautions may be necessary to avoid the risk of dust explosions and fires.

- Screens are essentially size separators based on perforated beds or wire mesh. Larger contaminants are removed from smaller food items: e.g. straw from cereal grains, or pods and twigs from peas. This is termed ‘scalping’.
- Alternatively, ‘dedusting’ is the removal of smaller particles, e.g. sand or dust, from larger food units.
- The main geometries are rotary drums (also known as reels or trommels), and flatbed designs.

![Diagram of screening process](image)

**Figure 1** Screening of dry particulate materials: (a) scalping, (b) dedusting.
Figure 2 9(a) Screen geometries: (b) principle of flatbed screen.
Abrasions, either by impact during the operation of the machinery, or aided by abrasive discs or brushes, can improve the efficiency of dry screens. Screening gives incomplete separations and is usually a preliminary cleaning stage.

Aspiration exploits the differences in aerodynamic properties of the food and the contaminants. It is widely used in the cleaning of cereals, but is also incorporated into equipment for cleaning peas and beans.

Principle of aspiration cleaning

The principle is to feed the raw material into a carefully controlled upward air stream. Denser material will fall, while lighter material will be blown away depending on the terminal velocity. Terminal velocity in this case can be defined as the velocity of upward air stream in which a particle remains stationary; and this depends on the density and projected area of the particles (as described by Stokes’ equation). By using different air velocities, it is possible to separate say wheat from lighter chaff or denser small stones. Very accurate separations are possible, but large amounts of energy are required to generate the air streams. Obviously the system is limited by the size of raw material units, but is particularly suitable for cleaning legumes and cereals.

Principle of aspiration cleaning

![Diagram of aspiration cleaning](image)

**Figure 3 Principle of aspiration cleaning**
Magnetic cleaning

- Magnetic cleaning is the removal of ferrous metal using permanent or electromagnets.
- Metal particles, derived from the growing field or picked up during transport or preliminary operations, constitute a hazard both to the consumer and to processing machinery, for example cereal mills. The geometry of magnetic cleaning systems can be quite variable: particulate foods may be passed over magnetised drums or magnetised conveyor belts, or powerful magnets may be located above conveyors. Electromagnets are easy to clean by turning off the power. Metal detectors are frequently employed prior to sensitive processing equipment as well as to protect consumers at the end of processing lines.

Electrostatic cleaning

- Electrostatic cleaning can be used in a limited number of cases where the surface charge on raw materials differs from contaminating particles.
- The principle can be used to distinguish grains from other seeds of similar geometry but different surface charge; and it has also been described for cleaning tea.
- The feed is conveyed on a charged belt and charged particles are attracted to an oppositely charged electrode according to their surface charge.

![Diagram of electrostatic cleaning](image)

**Figure 4** Principle of electrostatic cleaning.
Wet Cleaning Methods

- Wet methods are necessary if large quantities of soil are to be removed; and they are essential if detergents are used. However, they are expensive, as large quantities of high purity water are required and the same quantity of dirty effluent is produced.
- Treatment and reuse of water can reduce costs. Employing the countercurrent principle can reduce water requirements and effluent volumes if accurately controlled.
- Sanitising chemicals such as chlorine, citric acid and ozone are commonly used in wash waters, especially in association with peeling and size reduction, where reducing enzymic browning may also be an aim. Levels of 100–200 mg l–1 chlorine or citric acid may be used, although their effectiveness for decontamination has been questioned and they are not permitted in some countries.

Soaking is a preliminary stage in cleaning heavily contaminated materials, such as root crops, permitting softening of the soil and partial removal of stones and other contaminants. Metallic or concrete tanks or drums are employed; and these may be fitted with devices for agitating the water, including stirrers, paddles or mechanisms for rotating the entire drum. For delicate produce such as strawberries or asparagus, or products which trap dirt internally, e.g. celery, sparging air through the system may be helpful. The use of warm water or including detergents improves cleaning efficiency, especially where mineral oil is a possible contaminant, but adds to the expense and may damage the texture.

Spray washing

- Spray washing is very widely used for many types of food raw material. Efficiency depends on the volume and temperature of the water and time of exposure.
- As a general rule, small volumes of high pressure water give the most efficient dirt removal, but this is limited by product damage, especially to more delicate produce. With larger food pieces, it may be necessary to rotate the unit so that the whole surface is presented to the spray.
The two most common designs are drum washers and belt washers. Abrasion may contribute to the cleaning effect, but again must be limited in delicate units. Other designs include flexible rubber discs which gently brush the surface clean.

![Diagram of water spray cleaning](image)

**Figure 5** Water spray cleaning: (a) spray belt washer, (b) drum washer.

**Flotation washing**

- *Flotation washing employs buoyancy differences between food units and contaminants.* For instance sound fruit generally floats, while contaminating soil, stones or rotten fruits sink in water. Hence fluming fruit in water over a series of weirs gives very effective cleaning of fruit, peas and beans.

A disadvantage is high water use, thus recirculation of water should be incorporated.

- *Froth flotation is carried out to separate peas from contaminating weed seeds* and exploits surfactant effects. The peas are dipped in an oil/detergent emulsion and air is blown through the bed. This forms a foam which washes away the contaminating material and the cleaned peas can be spray washed.
Peeling

- Peeling of fruits and vegetables is frequently carried out in association with cleaning. Mechanical peeling methods require loosening of the skin using one of the following principles, depending on the structure of the food and the level of peeling required.
  - Steam is particularly suited to root crops. The units are exposed to high pressure steam for a fixed time and then the pressure is released causing steam to form under the surface of the skin, hence loosening it such that it can be removed with a water spray.
  - Lye (1–2% alkali) solution can be used to soften the skin which can again be removed by water sprays. There is, however, a danger of damage to the product.
  - Brine solutions can give a peeling effect but are probably less effective than the above methods.

Figure 6 Principle of flotation washing.
- Abrasion peeling employs carborundum rollers or rotating the product in a carborundum-lined bowl, followed by washing away the loosened skin. It is effective but here is a danger of high product loss by this method.
- Mechanical knives are suitable for peeling citrus fruits.
- Flame peeling is useful for onions, in which the outer layers are burnt off and charred skin is removed by high pressure hot water.

**Sorting and Grading**

- Sorting and grading are terms which are frequently used interchangeably in the food processing industry, but strictly speaking they are distinct operations. Sorting is a separation based on a single measurable property of raw material units, while grading is “the assessment of the overall quality of a food using a number of attributes”. Grading of fresh produce may also be defined as ‘sorting according to quality’, as sorting usually upgrades the product.

- Virtually all food products undergo some kind of sorting operation. There are a number of benefits, including the need for sorted units in weight-filling operations and the aesthetic and marketing advantages in providing units of uniform size or colour. In addition, it is much easier to control processes such as sterilisation, dehydration or freezing in sorted food units; and they are also better suited to mechanised operations such as size reduction, pitting or peeling.

**Criteria and Methods of Sorting**

- Sorting is carried out on the basis of individual physical properties.

- *Weight is usually the most precise method of sorting, as it is not dependent* on the geometry of the products.

- Eggs, fruit or vegetables may be separated into weight categories using spring-loaded, strain gauge or electronic weighing devices incorporated into conveying systems.
Using a series of tipping or compressed air blowing mechanisms set to trigger at progressively lesser weights, the heavier items are removed first, followed by the next weight category and so on.

These systems are computer controlled and can additionally provide data on quantities and size distributions from different growers.

An alternative system is to use the ‘catapult’ principle where units are thrown into different collecting chutes, depending on their weight, by spring-loaded catapult arms.

A disadvantage of weight sorting is the relatively long time required per unit; and other methods are more appropriate with smaller items such as legumes or cereals, or if faster throughput is required.

Size sorting

Size sorting is less precise than weight sorting, but is considerably cheaper.

The size and shape of food units are difficult to define precisely. Size categories could involve a number of physical parameters, including diameter, length or projected area.

Diameter of spheroidal units such as tomatoes or citrus fruits is conventionally considered to be orthogonal to the fruit stem, while length is coaxial. Therefore rotating the units on a conveyor can make size sorting more precise.

The main categories of screens are fixed aperture and variable aperture designs.

Flatbed and rotary screens are the main geometries of the fixed bed screen and a number of screens may be used in series or in parallel to sort units into several size categories simultaneously.

The problem with fixed screens is usually contacting the feed material with the screen, which may become blocked or overloaded. Fixed screens are often used with smaller particulate foods such as nuts or peas. Variable aperture screens have either a continuous diverging or stepwise diverging apertures. These are much more gentle and are commonly used with larger, more delicate items such as fruit.
Figure 7  Geometries of size sorting equipment : (a) concentric drum screen. (b) roller size sorter. (c) belt and roller sorter.

Shape sorting & Density

- Shape sorting is useful in cases where the food units are contaminated with particles of similar size and weight. This is particularly applicable to grain which may contain other seeds. The principle is that discs or cylinders with accurately shaped indentations will pick up seeds of the correct shape when rotated through the stock, while other shapes will remain in the feed.

- Density can be a marker of suitability for certain processes. The density of peas correlates well with tenderness and sweetness, while the solids content of potatoes, which determines suitability for manufacture of crisps and dried products, relates to density. Sorting on the basis of density can be achieved using flotation in brine at different concentrations.

Photometric properties
Photometric properties may be used as a basis for sorting. In practice this usually means colour.

- Colour is often a measure of maturity, presence of defects or the degree of processing. Manual colour sorting is carried out widely on conveyor belts or sorting tables, but is expensive.
- The process can be automated using highly accurate photocells which compare reflectance of food units to preset standards and can eject defective or wrongly coloured, e.g. blackened, units, usually by a blast of compressed air. This system is used for small particulate foods such as navy beans or maize kernels for canning, or nuts, rice and small fruit.

**Colour sorting**

- Extremely high throughputs have been reported. By using more than one photocell positioned at different angles, blemishes on large units such as potatoes can be detected.
- Colour sorting can also be used to separate materials which are to be processed separately, such as red and green tomatoes. It is feasible to use transmittance as a basis for sorting although, as most foods are completely opaque, very few opportunities are available. The principle has been used for sorting cherries with and without stones and for the internal examination, or ‘candling’, of eggs.

**Grading**

- Grading is classification on the basis of quality (incorporating commercial value, end use and official standards, and hence requires that some judgement on the acceptability of the food is made, based on simultaneous assessment of several properties, followed by separation into quality categories. Appropriate inspection belts or conveyors are designed to present the whole surface to the operator.
- Trained manual operators are frequently used to judge the quality, and may use comparison to charted standards, or even plastic models. For example, a fruit grader could simultaneously judge shape, colour, evenness of colour and degree of russetting in
apples. Egg candling involves inspection of eggs spun in front of a light so that many factors, including shell cracks, diseases, blood spots or fertilisation, can be detected.

- Machine grading is only feasible where quality of a food is linked to a single physical property and hence a sorting operation leads to different grades of material. Size of peas, for example, is related to tenderness and sweetness, therefore size sorting results in different quality grades.
- Grading of foods is also the determination of the quality of a batch. This can be done by human graders who assess the quality of random samples of foods such as cheese or butter, or meat inspectors who examine the quality of individual carcasses for a number of criteria.
- Alternatively, batches of some foods may be graded on the basis of laboratory analysis.

**Food Preservation and Protection**

- Six basic methods: dehydration, heating, freezing, fermentation, chemical preservation, or irradiation.
- Dehydration (drying)
  - prevents rotting of meat
  - Inhibits germination/sprouting of stored grains/vegetables
  - inhibits the growth of microorganisms
- Heating
  - destroys bacteria causing disease/spoilage
  - Examples: canning, pasteurization, and cooking
  - heated to a specific temperature for a specific time
- Freezing
  - basically stops bacterial growth and enzymatic activity
- Fermentation
  - gradual chemical change caused by the enzymes of bacteria, molds, and yeasts
- cheeses with a long shelf life are produced by lactic-acid fermentation
- Pickling-by treating foods with vinegar or some other acid

- Food additives have been
  - used for thousands of years
  - effective preservatives

- Irradiation
  - Exposing food to radiation source, most often Co$^{60}$ or Ce$^{137}$
  - beginning to be accepted in the food industry
  - kill pathogenic bacteria and spoilage microorganisms on everyday type foods
  - used on spices and other foods for over 50 years
- Processing methods
  - employed to utilize technologies to reduce/eliminate microbial loads on foods
Preliminary processing methods, conversion and preservation operation

Module- 7

Lec- 7

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Food and Food Processing

- Food is any substance, usually composed of carbohydrates, fats, proteins and water, that can be eaten or drunk by an animal or human for nutrition or pleasure.
- Items considered food may be sourced from plants, animals or other categories such as fungus or fermented products like alcohol.
- Food processing is the set of methods and techniques used to transform raw ingredients into food or to transform food into other forms for consumption by humans or animals either in the home or by the food processing industry.
- Food processing typically takes clean, harvested crops or slaughtered and butchered animal products and uses these to produce attractive, marketable and often long life food products. Similar process are used to produce animal feed.

History of Food Processing

- Food processing dates back to the prehistoric ages when crude processing incorporated slaughtering, fermenting, sun drying, preserving with salt, and various types of cooking (such as roasting, smoking, steaming, and oven baking).
- Evidence for the existence of these methods exists in the writings of the ancient Greek, Chaldean, Egyptian and Roman civilizations as well as archaeological evidence from Europe, North and South America and Asia.
- Modern food processing technology in the 19th and 20th century was largely developed to serve military needs. In 1809 Nicolas Appert invented a vacuum bottling technique that would supply food for French troops, and this contributed to the development of tinning and then canning by Peter Durand in 1810. Although initially expensive and somewhat hazardous due to the lead used in cans, canned goods would later become a staple around the world.
- Pasteurization, discovered by Louis Pasteur in 1862, was a significant advance in ensuring the micro-biological safety of food.
- In the 20th century, World War II, the space race and the rising consumer society in developed countries contributed to the growth of food processing with such advances as spray drying, juice concentrates, freeze drying and the introduction of artificial sweeteners, coloring agents, and preservatives such as sodium benzoate. In the late
20th century products such as dried instant soups, reconstituted fruits and juices, and self cooking meals such as MRE food ration were developed.

**Food Processing Methods**

- Removal of unwanted outer layers, such as potato peeling or the skinning of peaches.
- Chopping or slicing e.g. diced carrots.
- Mincing and macerating
- Liquefaction, such as to produce fruit juice
- Fermentation e.g. in beer breweries
- Emulsification
- Cooking, such as boiling, broiling, frying, steaming or grilling
- Deep frying
- Baking
- Mixing
- Addition of gas such as air entrainment for bread or gasification of soft drinks
- Drying
- Pasteurization
- Packaging
- Canning
- Irradiation
- Freezing
Figure 1 different types of food processing methods

Chocolate production

Potato Processing
Foods and Beverages

- **Foods**


- **Beverages**

Fruits & Vegetable Products

- **Raw mangoes:**
  Pickle, spread, candy, chunda, preserve, amchur, chutney, beverages
- **Ripe mangoes:**
  Pulp,(canned/aspetic) concentrate, juices, RTS, nectar, squash, crush, punch, jam, meva, bar, leather, toffee, mango burfee.
- **Pomegranate:**
  Juice, concentrates(Anarrub)necter, squash, crush, syrup/sherbat, purch, carbonated beverage, jelly, wine, anardana, anargoli/churn chutney, dalimbmanuka
- **Sweet orange:**
  Juice, concentrate marmalade, squash, cordial, segments candy, peel candy, segment preserve, wine, crush, punch, toffee, bar canned segment.
- **Jamun:**
  Pulp, juice, syrup, jam, jelly squash, spread, bar toffee, wine, vinegar, powder, flake.

- **Aloevera:**
  - Pulp, juice, squash, powder, wine, syrup gel, jelly, cosmetic products, oil, shampoo, powder, etc.
- **Aonla/Amla:**
  - Juice,RTS,chayvanprash
- **Ginger :**
  - Juice, RTS, dried ginger
- **Tamarind :**
  - concentrate, powder, slaps/block, pulp, syrup jam, jelly, sauce
- **Banana :**
  - Wafers/ chips, puree, juice, powder, vinegar, banana kig, snacks (chivada) jam, starch, fibre
- **Custard apple :**
  - Frozen, pulp, flakes, ice-cream, milk snakes, basundi, rabadi, toffee, seed : oil and cake. Grape raisin
Fruit & Vegetable Based Industries in India

- Integrated fruit and vegetable processing unit.
- Dehydrated fruits & vegetable unit.
- **Chips/ wafer unit -Banana/ potato / topioca.**
- Fruit bar, leather & toffee unit.
- Pickles, sauce, ketchup, chutney & soups.
- **Fruit candy, preserve, glazed fruits.**
- Herbal candy.
- Fruit jam, jelly, marmalade, fruit cheese, fruit butter
- Frozen fruits & vegetables & pulp.
- Aseptic packaging of fruit pulp.
- Fruit beverages unit.
- Carbonated fruit beverages, herbal juices & beverages
- Pectin manufacture.
- Citric acid production.
- Wheat grass juice.
- Herbal tea
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Food Preservation

Module- 17
Lec- 17

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Objectives

- Define food preservation
- Summarize five common historical methods of food preservation
- Describe current technologies for food preservation
- Discuss current trends in food preservation

Activity

- Why does fresh bread go bad?
- Why do fresh donuts go bad?
- Why do packaged bread or donuts not go bad?

Food Preservation

- Methods of treating foods to delay the deterioration of the food.
- Changing raw products into more stable forms that can be stored for longer periods of time.
- Allows any food to be available any time of the year in any area of the world.

Historical Methods of Food Preservation

- Primitive and tedious methods
  - Drying
  - Salting
  - Sugaring
Drying

- Used to preserve fruit, vegetables, meats, and fish.
- Mainly used in the south – warmer climate.
- Causes the loss of many natural vitamins.

Salting

- Used extensively for pork, beef, and fish.
- Costly due to high price of salt.
- Done mainly in cool weather followed by smoking.

Sugaring

- Used to preserve fruits for the winter.
- Jams and jellies.
- Expensive because sugar was scarce commodity in early America.

Pickling

- Fermenting
- Used to preserve vegetables.
• Use mild salt and vinegar brine.
• Increases the salt content and reduces the vitamin content of the food.
• Oldest form of food preservation.

Cold Storage
• Used extensively in the northern U.S.
• Root cellars were used to store vegetables at 30-40 degrees F.
• Root cellars were replaced by ice boxes in the mid 1800’s.

Factors Affecting Diet – Colonial Times
• Where you lived.
• Long winters in the north led to different diets in the south.
• Nutritious diets were unknown to early Americans.

Reasons for Dietary deficiencies
• Fruits and vegetables were available only during short seasons.
• Inadequate and time consuming food preservation methods.
• Lack of facilities for rapid transport of food from long distances.
• Contamination of food supplies.
Diet Today

• We can eat fresh vegetables from anywhere in the world today!!
  — Bananas
  — Strawberries
  — Pineapples

• Prior to 1930’s and 40’s food preservation basically remained as it was in colonial America.
  — Pickling,
  — salting,
  — sugaring,
  — cold storage,
  — drying.

Factors that Changed Food Science Technology

➤ Canning – revolutionized food preservation and made it more available.

➤ Commercial freezing and refrigeration – allowed preservation of meats.

➤ Refrigerated rail cars and trucks – increased the availability of fresh fruits, vegetables and meats.

➤ Food preservatives.

Food Preservatives
Retard or reduce the growth of undesirable microorganisms, mold and bacteria.

- Do not affect from food texture or taste.
- Safe for human consumption.
- Extend shelf-life of food.
  - Shelf-life – length time before a food product begins to spoil.

Today’s Food Industry

- Improvements have led to the replacement of the housewife as the major preparer or food preserver.
- Today it is done by machine and shipped to stores all over the world.

Food preservation is needed, especially today with the large world population.

Current Technologies in Food Preservation

- Activity
  - List the foods you like to eat all year.
  - Use this list to eliminate foods that were not available 10,20,30 years ago.
  - Eliminate foods not available in your area.
Types of Food Processing

- Heating
- Blanching
- Vacuum Packaging
- Drying
- Refrigeration
- Freezing
- Chemicals

Heating

- Started in 1800’s.
- Known as canning – putting hot food in jars to seal.
- Food is cooked to extremely high temperatures, put into jars and lids are placed on them.
- Lids are sealed from the heat and this prevents bacteria from growing and spoiling the food.

Blanching

- Used for vegetables.
- Heat the food with steam or hot water to 180-190 degrees F.
- This prevents bacteria from growing.
- Hot food is cooled in ice water.
Benefits of Blanching

- Shrinks the product, better for filling the container.
- Destroys enzymes in the food.
- Fixes the natural color of vegetables – holds their color.

Vacuum Packaging

- Removes oxygen.
- Oxygen reacts with food causing undesirable changes in color and flavor.

Drying

- Oldest form of food preservation.

Methods

- Sun drying
- Hot air drying – mechanical dehydrator
- Fluidized-bed drying
- Drum drying – milk, fruit, veg. juices, cereals
- Spray drying – milk, eggs, coffee, syrups
- Freeze drying -
- Puff drying – Fruit or vegetable juices
Refrigeration

• Early time, ice and snow was used.
• Now the most popular method of food preservation.
• 85% of all foods are refrigerated.
• Greatly changed our eating habits.

Freezing

• Used by Eskimos and Indians
• Frozen foods are a staple in every American home.

Chemicals

• Salt was first chemical used to preserve foods.
• NaCl – salt; makes water unavailable to microorganisms.
• Changes the pH of the food not allowing microorganisms to live.

Chemical Additives

- sodium nitrate
- fatty acids
- sulfur dioxide
- sorbic acid
- diethyl pyrocarbonate
- oxidizing agents
benzoates
antibiotics
antioxidants

Trends in Food Science

Key terms

- Monosaccharide – simplest carbohydrate; a sugar with a single molecule.
- Disaccharide – complex carbohydrate; sugar containing 2 monosaccharide sugars.
- Sucrose – table sugar; made from sugarcane or beets.
- Glucose – dextrose; monosaccharide less sweet than sucrose; made from corn.

Key terms

- NaCl – chemical form of salt; sodium chloride.
- Starch – complex molecule made of carbon, hydrogen and oxygen.

Scope of Food Industry

- Largest industry in U.S.
- Employs 14,000,000 people.
- Includes agricultural production, fishing, processing, transportation, wholesaling, retailing, warehousing, containerizing.
- Related to all other industries.
Most important industry to man.

Americans spend $100 billion annually for food; 1/5 of all spending.

World Trends Affecting Food Science

- Increase in world’s population is faster than increase in food supplies.
- Worsening worldwide food situation – large exports of grain; decrease in U.S. food reserves.
- Scientists must obtain high productivity from small amounts of land.
- Large food demand, small food supply.

What is the Supermarket?

- A business that allows for greater varieties of products and product forms, prepared foods, automatic vending, fast-order foods.

Development of the Supermarket

- Expanded food industry
- Large food stores and transportation has led to large shopping centers
- Offers lower prices, bigger selections
- Wal-mart, Target, SAMS

Salt

- Oldest known food additive.
Used in meats, cheeses, bread.

Americans consume 10-12 grams per day; 10 pounds per year.

Prevents spoilage.

3 basic properties

- Flavor
- Protein extraction
- Microbial control

Sugar

- Americans consume 147 pounds of sugar a year.
- Sources of energy.
- Consumed in excess leads to obesity.

Sweeteners

- Made from corn or chemicals.
- Americas usage of sweeteners changed agriculture.
- Sugarcane sales and production has dropped.
- Helps corn production.
Activity

- Using nutritional information
  - Find the sodium content
  - Convert the mg to ounces
  - Pour the equivalent amount of salt into a container.
  - Multiply mg times .02835 to get grams, then divide by 28.35 to get ounces.

Taste Test

- Unsweetened Iced Tea
  - Pitcher 1 – Honey
  - Pitcher 2 – Table sugar
  - Pitcher 3 – Corn syrup (fructose)
  - Pitcher 4 – Artificial sweetener
  - Is there a difference in taste?
  - Rank pitchers according to sweetness.
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:

  **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.
Technology and Food Additives – A History of Improvement

• The use of food additives is not a modern-day invention. The practice probably started when man first discovered that fire would cook and thereby preserve his meat. Later he realized that the addition of salt would preserve without cooking. In ancient times, cloves were placed in hams to inhibit the growth of bacteria; the Egyptians used food colors and seasonings, spices, flavors and condiments were considered so valuable as to serve as items of trade and, at times, objects of war.

• As the United States moved from the late 1800’s into the 20th century, sweeping changes took place throughout the country as Americans moved from a rural environment to a more industrialized society. Advances in farm mechanization and specialization, cross-country transportation systems, the advent of canning, and later the development of refrigeration, all had an impact on increasing this country’s food productivity to levels unheard of in previous times.

• As the 20th century progressed, the public’s demands for foods of high quality and convenience increased and could only be met by reasonably priced, packaged food.

• Technology has been able to meet demands that today we think of as imperative – variability, accessibility, freshness, palatability, uniformity – qualities that simply did not exist hundreds of years ago for even the richest, but are available for all today in the nearest supermarket.

• Industry continues to satisfy consumer demands as we advance technologically. With an ever increasing portion of our population employed in the working world, these qualities take on further importance, as we require high-quality, readily available foods.

Composition of Food Additives

• Every additive – like every food we consume – no matter what its source or intended purpose, is composed of chemicals.
• There is much discussion regarding “natural” and “synthetic” chemicals. Many of those synthesized in the laboratory are also found naturally-occurring in foods. Body metabolizes all chemicals similarly.

• For example, sugar found in sugarcane (sucrose) is no different in composition and function than refined sugar. Monosodium glutamate or MSG (a food additive used for its flavor enhancing qualities) and glutamate (a naturally-occurring amino acid found in many foods such as mushrooms and tomatoes) are metabolized by the body using the same normal biochemical pathways of digestion.

Food Additive Safety
• The question of food additive safety is one that has received widespread attention in recent years.

• It is important to understand the relativity of safety and be careful when using the words “toxic,” “harmful” and “safe.”

• The controlling factor in determining the safety of substances in our diet is quantity. Anything consumed in excessive amounts will be toxic, even those substances with which we are most familiar and in daily contact. There are no exceptions; anything from vitamins to water, if consumed in large enough quantities, will cause illness, and sometimes fatal effects.

• ‘Toxic’ is a relative term. The effects of any chemical substance or mixture depend not only on its composition and basic properties, but also on dosage, route and conditions of exposure, susceptibility of the organism exposed and other factors. It is not possible to categorize all chemical substances as ‘toxic’ or ‘non-toxic’ although some are more toxic than others during normal conditions of use and exposure and some are generally innocuous.

• One advantage of the wide variety of products available in our current food supply is that we can eat well-balanced, diverse foods. Besides being appetizing and appealing to our senses, this diversity affords us the opportunity of avoiding excess consumption of any one particular food, or food additive.

Testing Methods
• For direct additives, the first step is for the manufacturer (and/or others seeking approval) to conduct a battery of tests and chemical analyses to determine that a
A substance does what it is intended to do, and that it can be measured accurately in minute quantities. These tests assure that the usage can be checked, and that unwanted manufacturing by-products are adequately removed.

- A wide variety of animal tests are used to estimate the safety of a direct additive in the human diet. Because no animal is a perfect model, a number of different tests are used and the totality of scientific evidence must be evaluated and cautiously interpreted as to its relevance to man. Studies on metabolism, genetic toxicity, carcinogenicity and reproduction are among those required.

- Then further animal testing is conducted on at least two different types of laboratory animals. Large doses over extended periods of time are administered to determine whether an additive may be harmful over a lifetime of use. While rats and mice are commonly used, often a non-rodent is also studied.

- Detection of indirect additives and impurities has reached incredibly precise proportions allowing for identification of infinitesimally minute amounts of substances in foods. Just a few years ago the ability to test for one part per million concentration was considered quite a scientific feat, while now we can not only test for 1 part per million (1 ppm) but 1 part per billion (1 ppb) and even 1 part per trillion (1 ppt)! It is hard to envision the infinitesimally small quantities involved. For example, 1 ppt equals one grain of sugar in an Olympic-sized swimming pool.

Food Additives for a Better Food Supply

- In looking toward the future, increases in population will have a tremendous effect on the world’s food supply. There is much discussion regarding advances that must be made in order to meeting this growing demand. Food additives are making a major contribution to the goal of assuring a better supply of food through increased food production, improved nutritional quality, improved packaging, preservation, and distribution techniques, and replacement of dwindling supplies of natural resources.

- Food additives are largely responsible for the food supply to which we have grown accustomed. The consumer demands placed on technology have resulted in the development of additives that afford us abundant, convenient, nutritious, appetizing and economical foods. While the levels of use of food additives compared to our total diet are minor, their contributions have proven to be major.
References

- http://www.foodadditives.org/pdf/Food_Additives_Booklet.pdf
- http://www.understandingfoodadditives.org/
1.0 PACKAGING

Is the use of containers and components plus decoration or labeling to

(i) Protect
(ii) Contain
(iii) Identify
(iv) Merchandise
(v) And facilitate use of products.

One or a combination of these elements may be involved.

Today virtually every manufactured or processed food product required packaging in some phase of production or distribution.

Increasingly this packaging function requires specialized skills, machinery and facilities to produce packages that meet one or more of four basic demands

1. To make it easier and safer to transport
2. To protect the product against contamination or loss
3. To protect against damage or degradation
4. To provide a convenient means of dispensing to the exterior

The Addition of printing or other decoration to the exterior of packages serve

(a) To identify the contents as to types and quantity
(b) Identify the manufacturers brand and quality grade
(c) Attract the buyer’s attention

(d) Persuade buyer to purchase

(e) Instruct purchaser on how to use the product

BACKGROUND:

Food containers and their utilization go back to the dawn of history. Food items to be stored or transported called for packaging. Many different things were used:

- Leaves
- Hollowed-out plant limbs
- Gourds
- Skins
- Reed Baskets
- Earthenware vessels

In time containers were improved or developed to meet the special needs of nomadic tribes:

- Agrarians
- Merchants, traders and even for religions and war

The antecedents of some modern containers such as glass bottles and certain packaging practices like labeling are very old.

Glass bottles were used in Egypt more than 4,000 years ago. Marks and signatures, symbols and seals of various types appeared on the very first glass bottles used in commerce. The earliest paper originated from China about 200 B.C. Egyptians and Greeks used it about 500 B.C. and the Arabs learned the art from the Chinese during the Chinese invasion of 751 AD.
The tin can owes its origin to the discovery in 1200 AD by Bohemian artisans of a hot dip process for plating tin onto thin sheets of iron. The Romans used lead in many ways including water pipes and ointment jars.

Until about 1800, the making of packages was a craft or an art. It was the industrial revolution which produced advances in containers invention and fabrication resulting in the container forms we are familiar with today.

- Metal cans
- Glass jars
- Collapsible tube
- Folding Carton
- Corrugated shipping case
- And crown caps for bottles.

During the latter part of the 19th century into the early part of the 20th century, the groundwork was laid for mechanized production of all standard container forms. Simultaneously with this, linotype, photoengraving, process colour-printing and several graphic-art processes were developed thus completing the combination of container + effective decoration which has made modern packaging possible.

Between 1900-1930 several revolutionary products were discovered:

- Glassine
- Kraft paper
- Cellophane
- Aluminium foil

These provided the basis for a whole new development in
FLEXIBLE PACKAGING

The search for new materials thus stimulated by these discoveries has lead to spectacular discoveries since 1940 when

- Polyethylene
- Polyester
- Polypropylene
- Stretchable paper
- Steel foil
- Ionomers and a host of improved, coated or
- Laminated materials were introduced

Development of sophisticated merchandizing techniques was occurring parallel to that in packages making. It is these two mutually related factors which lead to the flood of packaged products that has never stopped growing in volume and variety. We are now in the era of CONVENIENCE PACKAGING.

Right along with these developments, machinery has been evolved for all phases handling, filling, closing, labeling and shipping of packaged products. Lines of machinery tailored to the needs of every conceivable food product and any type of container can be found. A new science of packaging management and packaging methods has been born.
LECTURE 2

2.0 MODERN PACKAGING MATERIALS AND PACKAGE FORMS

2.1 A RIGID PACKAGING MATERIALS AND PACKAGE FORMS

2.1.1 GLASS CONTAINERS

Glass = Limestone + Sand + Soda Ash + Alumina

Colorants may be added to the melt or introduced later

ADVANTAGE

- It is strong, rigid, chemically inert
- It is an excellent barrier against solids, liquids and gases
- It does not deteriorate appreciably with age
- It is low-cost (7/1b in finished delivered container)
- Its transparency (gives excellent product visibility)
- Attractive finishes of a variety of types are possible
- Extremely versatile, as to size and shape

DISADVANTAGES

- Weight – heavy
- Fragility in transport, Not easy to dispose of
### 2.2 TYPES OF GLASS CONTAINERS

<table>
<thead>
<tr>
<th>(i)</th>
<th>(ii)</th>
<th>(iii)</th>
<th>(iv)</th>
<th>(v)</th>
<th>(vi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOTTLES</td>
<td>JARS</td>
<td>TUMLERS</td>
<td>JUGS</td>
<td>CARBOYS</td>
<td>VIALS &amp; AMPOULES</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shape</th>
<th>High usage</th>
<th>Wide-mouthed</th>
<th>Open-ended</th>
<th>Large sized</th>
<th>Heavy shipping</th>
<th>Small container</th>
</tr>
</thead>
<tbody>
<tr>
<td>narrow</td>
<td>short-necked</td>
<td>necks at all Bottles containers</td>
<td>pharmaceuticals,</td>
<td>large liquids Jellies handle short colorants</td>
<td>bodies solids short necked</td>
<td>liquids or semi-small size liquid narrow-necked bottles 3</td>
</tr>
</tbody>
</table>
2.3 CONSIDERATIONS IN CHOOSING GLASS CONTAINERS FOR FOOD

DIMENSIONS AND “FINISH”:- Ensure that volume is adequate product is easily filled and dispensed

Proper closure can be selected

“FINISH”:- Refers to type of and dimensions of neck and mouth of container i.e THREAD, LUD, FRICTION, SNAP-ON, ROLL-ON

Many standard finishers are listed by the glass containers manufactures institute

COLOUR:- Influence type of light reaching the food

ABILITY TO RESIST THERMAL SHOCK:- This is important in heating and cooling operations.

LECTURE 3

3.0 METAL CANS

Consists of steel base sheet with a tin coating. The tin is applied by hot dip or electrolytically. Electrolytic application can be done differentially so that the two sides of the tin plate have different thickness of tin coating.

3.1 LAQUERS, Enamels

Besides the tin coating other organic coatings are also applied. These coatings must be non-toxic and free from odors and tastes. They must not come loose during processing or storage
These coatings consist of

<table>
<thead>
<tr>
<th>INTERIOR</th>
<th>EXTERIOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylics</td>
<td>Acrylics</td>
</tr>
<tr>
<td>Alkyds</td>
<td>Alkyds</td>
</tr>
<tr>
<td>Butadienes, epoxyamine</td>
<td>Oleoresins</td>
</tr>
<tr>
<td>Epoxyester, epoxy-phenolics</td>
<td>Phenolics</td>
</tr>
<tr>
<td>Oleoresins, Phenolics</td>
<td>Vinlys</td>
</tr>
<tr>
<td>Vinlys</td>
<td></td>
</tr>
</tbody>
</table>

Since 1959 – Aluminum is being used for beers, concentrated frozen fruit juice, frozen baked goods, powdered milk, condensed milk. An interior coating is generally necessary for Aluminum.

<table>
<thead>
<tr>
<th>Advantages of metal cans</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strong</td>
<td>1. Heavy</td>
</tr>
<tr>
<td>2. High speed manufacturing, filling and closing</td>
<td>2. cannot be re-closed</td>
</tr>
<tr>
<td></td>
<td>3. Not disposable</td>
</tr>
</tbody>
</table>

3.2 COMPOSITE CONTAINERS

This is made from 2 or more constituent materials

Usually = Paper Board Body + Metal or plastic Ends

Two types:
(a) Spiral wound containers – made in cylindrical shapes where two or more plies of board are glued together around a mandrel.

(b) Convolute – wound composites – produced by straight winding.

3.3 AEROSOL CONTAINERS

Uses
- Beverage concentrates
- Cocktail mixes
- Cake icings
- Pancake mixes
- Syrups
- Salad Dressings and seasonings

3.4 RIGID PLASTIC PACKAGES

Advantages
- Low cost
- Ease of Fabrication

Disadvantages
- Lack of product compatibility
- Low barrier properties
- Plastic deterioration
- Low heat resistance
- Fragility at low temperature.

3.5 MAIN TYPES OF PLASTIC CONTAINERS

<table>
<thead>
<tr>
<th>Thermoformed</th>
<th>Injection-Molded</th>
<th>Blow-Molded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart treated plastic is</td>
<td>Used in high volume</td>
<td>Used where containers have...</td>
</tr>
</tbody>
</table>
formed around a mold. They may be pressure or vacuum formed. Plas
astics used are polyvinyl chloride polystyrene, polypropylene ABS (Acrylonitrile butadiene styrene) Cellulose acetate. Trays are made with – this method.

| applications for jars bottles and tubs. Plastics used are: polypropylene, polystyrene. Has outstanding clarity compared with rest of body. Plastic used are: Polyvinyl chloride polypropylene, polycarbonate, Cellulose Acetate Polystyrene polyethylene, polyacetate. |

3.6 SOLID AND CORRUGATED FIBERBOARD CONTAINERS

Used to fabricate shipping cartons and cases

Used in wholesale and industrial shipping.

3.7 WOODEN BOXES AND CRATES

Used when timber is plentiful and inexpensive for shipping purpose.

3.8 CYLINDRICAL SHIPPING CONTAINER

Have high stacking strength

Can be rolled in Handling

They are made from fiberboard

Glass, metal, plastic or wood

Glass containers have been used as liners for other shells from: steel aluminium, fiberboard or wood
BARRELS  Metal barrels made of steel or aluminium

DRUM

PAIL

KEG  Small barrel

CASK  Large, light wooden barrel

3.9 CONTAINERIZATION

Purpose is safe transport of goods from point of manufacture to sales point economically. Concept is to use as freight, container which is delivered directly to factory from loading point. At point of use container is directly off-loaded.

LECTURE 4

4.0 SEMI-RIGID PACKAGING MATERIALS AND PACKAGE FORMS

4.1 ALUMINIUM CONTAINERS

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Convenience in preparation and serving of food. They withstand high temperature foods can be frozen in packages or cooled in it.</td>
<td>High cost as at now high technology of high capital intensity.</td>
</tr>
<tr>
<td>2. Protects food as an excellent barrier</td>
<td></td>
</tr>
<tr>
<td>3. Very Light</td>
<td></td>
</tr>
</tbody>
</table>

Types:  Folded end

Ovals
Pie Plates
Rectangular
Rounds
Squares
Specialty Items

4.2 SET-UP PAPERBOARD BOXES

Four Basic components

(i) Paperboard
(ii) Adhesive
(iii) Coner Stays
(iv) Covering

Advantages: Convenience
Individuality
Strength
Reusability
Excellent Protection

Disadvantage: High cost

4.3 FOLDING PAPERBOARD CARTONS

4.4 MOLDED PULP CONTAINERS

LECTURE 5

5.1 METAL CANS
More than 49 billion metal cans are manufactured in the U.S. annually. This accounts for more than 30% of all units of consumer packaging.

The tin container was invented in 1810 by Peter Durand an English man. It was introduced to the U.S. in the 1820’s. At that time cans generally were made by hand. They were made during the winter months for use along with the next harvest. An expert can maker would produce 5 or 6 cans/hour.

“Sanitary” can was developed about 1900. This paved the way for mechanization. The Metal Box Company is the only producer in Nigeria. At the moment they are making mainly No Al-type Cans. The total quality of cans manufactured are probably very much below the 10 million mark.

5.2 TIN PLATE CANS

Consist of a steel base sheet with a tin coating.

(a) the steel base plate is usually about 0.01 thick

(b) the tin coating has thickness varying from $15 \times 10^{-6}$ inches thick

(c) Can enamels (Laquers) are baked organic coatings which are applied to improve stability of can interior when susceptible to damage by food materials packed in it.

The tin plate is an ideal material for food containers. Tin is not completely inert to all food. But corrosion and product chances are small if the proper choice of material is made.

Among the many factors considered by can manufactures are:

1. Chemical composition and physical properties of base plate

2. Thickness of tin coating
3. Application of protective coating or enamels

4. Container construction

5. Relative corrosivity of the product to be canned.

A large number tests are conducted prior to adoption of material.

5.3 A BASE PLATE

This is low carbon steel.

Metalloid content particularly of phosphorus, silicon are critical. Other trace metals of importance are copper, nickel, molybdenum. The amount of these elements affect the corrosion resistance of the base plate.

Four Basic types of metal are used and a 5th is used for beer can ends

<table>
<thead>
<tr>
<th>Element</th>
<th>% Permitted</th>
<th>Type L</th>
<th>Type MS</th>
<th>Type MR</th>
<th>Type MC</th>
<th>Beer End Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>0.25-0.60</td>
<td>0.25-0.60</td>
<td>0.25-0.60</td>
<td>0.25-0.60</td>
<td>0.25-0.70</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>0.12 max</td>
<td>0.12 max</td>
<td>0.12 max</td>
<td>0.12 max</td>
<td>0.15 max</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.015 max</td>
<td>0.015 max</td>
<td>0.02 max</td>
<td>0.07-0.11</td>
<td>0.10-0.15</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.05 max</td>
<td>0.05 max</td>
<td>0.05 max</td>
<td>0.05 max</td>
<td>0.05 max</td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>0.01 max</td>
<td>0.01 max</td>
<td>0.01 max</td>
<td>0.01 max</td>
<td>0.01 max</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>0.06 max</td>
<td>0.10-0.20</td>
<td>0.20 max</td>
<td>0.02 max</td>
<td>0.20 max</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>0.04 max</td>
<td>0.04 max</td>
<td>No limit</td>
<td>No limit</td>
<td>No limit</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>0.06 max</td>
<td>0.06 max</td>
<td>No limit</td>
<td>No limit</td>
<td>No limit</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.05 max</td>
<td>0.05 max</td>
<td>No limit</td>
<td>No limit</td>
<td>No limit</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.02 max</td>
<td>0.02 max</td>
<td>No limit</td>
<td>No limit</td>
<td>No limit</td>
<td></td>
</tr>
</tbody>
</table>
### 5.4 CLASSES OF FOOD PRODUCTS AND TYPES OF STEEL BASE REQUIRED

<table>
<thead>
<tr>
<th>Class Food</th>
<th>Characteristics</th>
<th>Steel Base Rqd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most strongly corrosive</td>
<td>Highly or moderately Acid Foods</td>
<td>Type L</td>
</tr>
<tr>
<td>Moderately corrosive</td>
<td>Acidified vegetables, midly acid food products</td>
<td>Type MR, Type MC</td>
</tr>
<tr>
<td>Midly corrosive</td>
<td>Low acid foods</td>
<td>Type MR, Type MC</td>
</tr>
<tr>
<td>Non corrosive</td>
<td>Mostly dry and non processed products</td>
<td>Type MR, Type MC</td>
</tr>
</tbody>
</table>

**TERM BASE BOX:** You will come across this term repeatedly. Originally Tin plate was sold in only one size sheet 14” x 20”, 112 sheets – 1 Base Box. Such a package contained 31,360 in or 217.78 ft² of surface.

**TIN COATING**

This is applied by either hot dip or by electroplating. Today only about 6% of all tin cans are made by hot dip which produce non-uniform tin coating.

Electrolytic plating can be differentially applied so that the inside and outside surface have different thickness of tin coating.

- **Hot dip**: (1.25 1b/Base box) of tin
- **Electrolytic**: (0.52 1b/Base box) of tin

**ENAMEL COATING**
These are baked organic coating, normally applied by roller to the flat sheet and are baked at temperatures below the melting point of tin.

Their purpose

(1) Preserve attractiveness of food in CAN

(2) Improve interior (occasionally only) exterior of can

(3) Increase shelf life of can

(4) Coating may make it possible to use less expansive tin coating

5.5 GENERAL TYPES OF ENAMEL COATING

<table>
<thead>
<tr>
<th>Coating</th>
<th>Typical Uses</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fruit Enamel</td>
<td>Fruits requiring protection from metallic salts e.g cherries</td>
<td>Oleoresinous</td>
</tr>
<tr>
<td>2. C-Enamel</td>
<td>Corn, peas and other sulfur-bearing products, including some sea foods</td>
<td>Oleoresinous with suspended zinc oxide pigment</td>
</tr>
<tr>
<td>3. Citrus Enamel</td>
<td>Citrus products and concentrates</td>
<td>Modified Oleoresinous</td>
</tr>
<tr>
<td>4. Sea foods Enamel</td>
<td>Fish products and meat spreads</td>
<td>Phenolic</td>
</tr>
<tr>
<td>5. Meat Enamel</td>
<td>Meat and various specialty products</td>
<td>Modified epons with aluminium pigment</td>
</tr>
<tr>
<td>6. Milk Enamel</td>
<td>Milk, eggs and other dairy products</td>
<td>Epons</td>
</tr>
<tr>
<td><strong>7. Beverage CAN enamel</strong> (non-carbonated)</td>
<td>Vegetable juices, fruit juice, highly corrosive fruits, non-carbonated beverages</td>
<td>Two-coat system with Oleoresinous type base coat and vinyl top coat</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>------------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>8. Beer Can Enamel</strong></td>
<td>Beer and carbonated beverages</td>
<td>Two-coat system with Oleoresinous or polybutadiene type base coat and vinyl top coat.</td>
</tr>
</tbody>
</table>

## 5.6 CAN MANUFACTURING

Modern process is highly mechanized. Can bodies are formed at speeds as fast as 600 units per minutes

1. Interior Enamel and outside lithography if used are applied to flat sheets of plate
2. Coated sheets are cut into proper size for individual can bodies
3. “Body Blanks” are fed into bodymaker which notches, edges and curls the plate so that the opposite sides lock together
4. The four thicknesses of metal which meet at the side seam are “bumped” flat and soldered (tin solder) forming a cylindrical shell.
5. The flanger puts a flared rim on both ends of the can body
6. When needed, a second coat of enamel is sometimes sprayed into the formed can body
7. One end (bottom) is double-seamed into the can body and the can is tested under pressure.
CAN ENDS: Are stamped from enameled or uncoated sheets of plate which have been out into strips of proper size.

The edge of the end is curled to form a groove. Into the groove, a heavy liquid rubber sealant is flowed. This gasket-like material, when dried, provided an hermetic meal in the double seam between body and end.

One can end is double seamed at the factory. The second is double seamed by the packer.

5.7 CIRCUMFERENTIAL BEADS

Those are used on large cans to provide strength. It increases resistance to rough handling and improves can ability to withstand paneling pressure.

5.8 QUALITY CONTROL CANS

The can manufacturer assumes responsibility for quality of tin plate in finished product. Microscopic pores or flaws in the plate may expose base plate and accelerate corrosion. Micro examination is done. Tests have been devised for checking continuity of tin coating.

5.9 (a) Pickle Lag Test

Detinned sample in immersed in HCl. The rate at which H₂ is given off by corroding plate is recorded. Good plate is attached at a content rate throughout the test. Poor plate is attached critically.

(b) Iron Solution Value (ISV)

This simulates reaction with a filled tin can. It measures amt. of iron dissolved from a tin plate specimen immersed for several hrs. in acid solution.

(c) Tin crystal size: test samples are etched for 10-15 seconds in acid solution, to bring out the pattern of crystals on the plate large crystals are desirable.
LECTURE 6

6.0 FLEXIBLE PACKAGING MATERIAL

These generally fall into two broad categories

1. Paper and 2. Films

6.1 PAPER – Consist of bonds, tissues, litho, krafts, glassiness parchment and greaseproof.

<table>
<thead>
<tr>
<th>PAPER TYPE</th>
<th>MATERIAL</th>
<th>WTS/3000ft²</th>
<th>USES AND FINISHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Bands</td>
<td>Uncoated sheets made of bleached chemical pulp</td>
<td>20-70 lbs/3000 ft²</td>
<td>Wide variety of finishers for printing. May have high degrees of wet strength etc.</td>
</tr>
<tr>
<td>(ii) Tissues</td>
<td>Light wt paper made of semi-fully bleached chem. pulp</td>
<td>8-20 lbs/3000 ft²</td>
<td>Wide variety of strength and porosity. They may be glazed etc. use as wraps</td>
</tr>
<tr>
<td>(iii) Litho</td>
<td>Coated on one or both side</td>
<td>29-60 lbs</td>
<td>Used in publication advertising Excellent printing properties used in beer labels</td>
</tr>
<tr>
<td>(iv) Krafts</td>
<td>Very strong paper, made in bleached or unbleached form</td>
<td>25-80 lbs</td>
<td>Wide variety of strength available they are porolls and roughly finished. They are sheap. Used in making cannister labels</td>
</tr>
<tr>
<td>(v) Glassines</td>
<td>Super calendered chemical pulp sheet</td>
<td>15-45 lbs</td>
<td>Have high resistance to air and grease. Very strong, have smooth surface and glossy. Used for candy wraps</td>
</tr>
<tr>
<td>(vi) Parchment</td>
<td>Bleached chemical pulp stiped in $H_2SO_4$</td>
<td>15-27 lbs</td>
<td>Good grace resistance, good wet strength used for butter and magarine wraps</td>
</tr>
<tr>
<td>(vii) Greese Proof</td>
<td></td>
<td></td>
<td>Very much like parchment paper.</td>
</tr>
</tbody>
</table>

6.2 FILM
Definition: Thin flexible plastic sheeting having a thickness of 0.0100 inch or less. They are flexible as a result of manufacturing processes.

6.3 PLASTIC FILMS

(i) Cellophane

Originated as a brand name for a regenerated cellulose film. Transparent, somewhat elastic heat-resistant, water and oil insoluble film.

Produced by precipitating viscose solution with ammonium salts. When dry, cellophane film is relatively GAS TIGHT, when wet it loins much of its imperviousness to gas. Its lowest rated property is lack of flexibility. It therefore breaks easily when used with dry products. Cellophane is often used with other plastic films in laminates. Cellophane to cellophane is not heat sealabl but it easily accepts heat sealable coating. Cellophane should be used immediately after exposure to high PV or immediately after exposure to low temperature.

(ii) CELLULOSE ACETATES

Closely resembles cellophane as far as most properties go except in two respects

1. Gas Transfer 2. Water Transfer

Cellulose acetate is better in water transfer resistance than in GAS TRANSFER resistance.

Because of its permeability to GAS it is suited for packaging certain fresh products such as fruits and vegetables.

It is not used for meat because its transmission rate of water is high and shrinkage and surface drying of fresh meat will result.
Cellulose acetate is derived from cellulose treated with acetic acid anhydride. The cellulose triacetate is partially hydrolyzed. Additives include plasticizers, antiblocking agents U.V absorbers. Used where stiffness, gloss and dimensional stability are required. Cellulose acetate is sealed commercially with solvent adhesives. It have a wide use in laminates. Used extensively with polyethylene.

(iii) Polystyrene: A polymer of styrene. Its tensile properties are good as a film only at temperature above 176°F.

It has attracted considerable attention in recent times because of its remarkable resistance to RADIATION include CHANGE. It is three times as resistant to radiation as polyethylene.

(iv) Polyethylene: the largest volume single film produced. Its primary selling point is its high functional properties as well as low cost.

In 1960 consumption of polyethylene in U.S.A was 280 million pounds.

In 1970 U.K. consumption 315,000 tons.

It is a polymer of ethylene and it obtained by two processes.

(a) High Pressure polyethylene

Or

Low density film

Manufactured at temperature 302-392°F pressure of 1200 atmospheres traces of O₂ present

(b) Low Pressure or high Density Film

Temperature 140-320°F, Pressure 40 atmosphere with Alkylmetal catalysts.

Low density polyethylene is lower cost of the two.
Has moderate tensile strength and clarity. It is a good moisture barrier and poor O₂ barrier. Not affected by mineral oils. Easily fused for closure. Density ranges are 0.926-0.940 medium 0.910-0.926 low.

High density film offers better moisture protection and increased heat stability. Density ranges are 0.941-0.965 polythene bonds with cellophane to make good laminates. Printability is a problem it will not take printing ink, but by crafting polyacrylamide, a hydrophilic polymer on polyethylene, a polyethylene hybrid is produced whose surface will take ink. Extensive use of polyethylene is made in the retail market.

(v) Polyamides - Nylons

Various grades are available

Nylon 6 – Ease in handling and good abrasion resistance

Nylon 11 and Nylon 12: Superior barriers to O₂ and water and have low heat seal temperature.

Nylon 66: Very high melting temperature, difficult to seal.

(vi) Polyvinylchloride: Used for dairy, meat, confectionery and beverage packaging as well as laminate component.
LECTURE 7

7.0 PLASTIC FILM CONTINUE

7.1 POLYVINYLIDENE CHLORIDE (SARAN FILMS)

Saran is a copolymer of POLYVINYLIDENE chloride and polyvinylchloride.

It is one of the best films for imperviousness to water vapour, gases and odour. This property together with its ability to shrink when treated by simple method has given it a wide scope for food package uses.

The form having the trade name of cryovac shrinks to the extent of 30% when immersed in water at 200 to 205°F. The sarans are clear, have good mechanical resistance, low water vapour and gas transmission rates.

Uses for cheese, meats, sausages, dried fruits wrappers etc. saran films are highly resistant chemically and are varied in composition or given an appropriate coating to increases resistance to specific products. It takes printing and can be marked with a pen.

In heat sealing it tends to shrink away from sealing bars resulting in reduction of thickness and weakening of the film along the edge of the seal. In practice this effect is minimized by intensifying the application of heat and using very short heating period so as not to allow much time for shrinkage to take place. This produce is called impulses sealing. For heat sealing of sarans the heating bars are covered with TEFLON to prevent sticking on the bars.

STORAGE TEMPERATURE AFFECT THE PROPERTIES OF SARANS

- 1 year at 95°F - lose 1/3 or shrinking ability
- 1 year at 115°F - lose 1/2 or shrinking ability
- At 40°F - loss of shrinking ability
Stored below 40°F SARAN loses pliability

The film is resistant to most solvent.

Saran was first produced in 1946. It was developed as a substitute for a natural rubber shrinkable film developed just before World War II when rubber had become scarce.

The Cryovac film is extruded by means of a special screw-type device.

A trapped gas bubble is employed to bring about the required orientation of molecules.

Finely powered vinylidene-vinyl copolymer, mixed with plasticizers, stabilizers, dyes, pigments and other agents is fed in extruder is heated for the necessary time at accurately controlled temperature above the melting point.

The syrupy extrude passes through a circular die into COLD WATER, thus producing a super cooled tube of amorphous material using gas pressure, the tube is expanded to 4-times its super cooled diameter, causing the material to be stretched simultaneously in all directions. This orients the long chain molecules bioxially to give the film its quality of uniform shrinkability.

(viii) Polyester

The ester polymer are films of unusual strength and of light weight they have various compositions, depending upon the identities of alcohols and acid from which they are formed. A popular type is polyethylene terephthalate, a polyester of ethylene glycol and TEREPTHALIC ACID. This is called MYLAR. Mylar was first produced in 1954.

It has a great tensile strength elasticity and STABILITY over a wide range of temperature (-80°F-300°F).
Used in pouches for frozen food as well as other products which may be heated to boiling water temperature. For this application polyester is laminated with polyethylene. The laminate is used in most “heat in pouch” packaging of food.

Manufactured in thickness from 0.00025-0.0075 inches. They are much more expensive than polyethylene, cellophane or cellulose acetate.

Polyester films are made heat-sealable by treatment with certain substances. One of these substance is BENZYL ALCHHOL. Sealing Bars are covered with TEFLON.

POLYESTER comes nearer than any other film used today to having properties required of a film for packaging sterilized foods.

It has strength and stability but does not meet the requirements for imperviousness to gases and water vapour.

Its melting points is 482°F and thus high temperature sterilization is possible.

It has clarity and has good printability.

It is used for vacuum packing of products.

POLYPROPYLENE

High potential use of this film is anticipated in the food industry. Presently used for bakery and confectionery goods. It has low density, excellent strength and stability with good shrinking properties. The film may develop into a real competitor of polyester film for “heat-in-the-pouch” packaging.

RUBBER HYDROCHLORIDE (Pliofilm)

Produced from Natural rubber by the addition of hydrochloric acid. It is stretchable, non toxic, good oil and grease resistance used for self service packages for meats, cheese. Bags lined with ploifilm are used for coffee, spices and cookie packaging.
The film has fairly good imperviousness to water vapour. But it is coated with other plastics to give it differing degrees of permeability. Has good film-to-film heat sealing properties. It is used in identical circumstances as polyethylene. It makes good laminates with a variety of other materials.

**ALUMINUM FOIL**

**Advantages**

1. Large covering area per pound of material
2. Opacity
3. Almost absolute imperviousness to water vapour and gas in higher gages and good imperviousness in low gages.

   However, in thickness less than, 0.0015 in aluminum foil contains small perforations which makes it pervious to gases and vapours.

   Aluminum foil is unaffected by sunlight, does not burn. It is non absorptive of water and thus does not exhibit dimensional change with variations in humidity. Intermetent contact with water has very little effect. But hygroscopic products packaged in thin foil may cause some reactions particularly if product contains salts and organic acids as do mayonnaise and cheese.

   Use: candies, milk, unsalted meats, butter and Oleomargarine. Can be used safely with oils and greases. Commercially aluminium foils are not used with strong mineral acids which will cause severe corrosion but weak acids found in food products do not, have appreciable effects.

   The only safe rule with new products is to make suitable tests. To protect aluminum foils against corrosive materials, protective coating may sometimes be applied.
Mechanical Properties of aluminum foil

Tensile strength of annealed foil = 8.5 Lbs/in of width/mil of thickness. Strain hardening increase tensile strength for bursting and tearing while the tensile strength is relatively high, advantage cannot always be taken of it in foil packages. Economic considerations may dictate the use of thinner gages with reliance on laminations with other materials e.g. plastic films or paper to increase strength.

One important property of aluminum foils is that they do not become brittle at low temperatures. In fact aluminum foil increases in strength and ductility as temperature is lowered down to 320°F.

TESTS OF MEASURE CHEMICAL AND PHYSICAL PROPERTIES OF FLEXIBLE PACKAGING MATERIALS

BURSTING STRENGTH: (Mullen Burst Tester)

Increasing pressure of a rubber hydraulic bubble against sample of sheet or film, clamped between two jaws having coincident circular openings, bursts the sample which ahs closed the circular opening. Unit : (psi)

TENSILE STRENGTH AND ELONGATION (Baldwin Static – Weighing machine; Pendulum – Weighing machine)

Each end of a sample strip 1” wide is clamped between a pair of jaws. A load applied to one set of jaws, tending to stretch the sample is increased gradually until sample breaks in two.

Units: (elongation (%))

Tensile strength (Lb/in-width/thickness)

GAS TRANSMISSION
Sample of sheet of film, sealed across an opening in wall of a vacuum chamber, transmits gas from outside to inside the chamber, causing pressure in chamber to increase

Unit: (cc/100 in²/24 hours).

**WATER VAPOUR TRANSMISSION**

Sample of sheet or film, sealed across mouth of a cup containing a substance that absorbs water readily, transmits water vapour from atmosphere at 90% R.H. at 100°F outside cup causing dessicant to increase in wt.

Unit: (grams/100 in²/24 hours).

**GREASE RESISTANCE**

Sample of sheet or film of specified size (4” x 4”) intimate contact with white paper is treated on the other surface with test reagent (grease or oil).

Unit: time (minutes or hours) required for first appearance of stain on the paper.

**AGING**

Sample of packaged product is alternately exposed to different aging conditions, such as wet and dry heat at 160°F, extreme variations of temperature.

Extreme variations of R.H.

Various types of rays or extreme variations of free oz-concentration.

At proper intervals, sample is examined for product deterioration, changes in wt and dimensions, dulling, crazing (i.e. collapsing), warping and discoloration.
# OTHER INSTRUMENTS

## OTHER INSTRUMENTS ARE LISTED AS FOLLOWS

<table>
<thead>
<tr>
<th>S/N</th>
<th>Instruments</th>
<th>Property Tested by Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tear Test (Elmendorf)</td>
<td>Tear resistance (gram/mil)</td>
</tr>
<tr>
<td>2</td>
<td>Folding Endurance or stiffness Tester (MIT)</td>
<td>Pliability or resistance to bending</td>
</tr>
<tr>
<td>3</td>
<td>HEAT SEALER</td>
<td>Temp. Required to seal (°F)</td>
</tr>
<tr>
<td>4</td>
<td>Size Tester</td>
<td>Moisture absorptiveness (% increase in wt)</td>
</tr>
<tr>
<td>5</td>
<td>Climatizer or Testing Cabinet</td>
<td>Holds controlled conditions of R.H. and Temperature</td>
</tr>
<tr>
<td>6</td>
<td>SPI TESTER</td>
<td>Flammability</td>
</tr>
</tbody>
</table>