U.P. Rajarshi Tandon Open University, Prayagraj

HUMAN NUTRITION

HNSEC-04

TECHNIQUES OF FOOD PRESERVATION

COURSE CONTENT

HNSEC-04 TECHNIQUES OF FOOD PRESERVATION

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HNSEC-04 TECHNIQUES OF FOOD PRESERVATION

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HNSEC-04

TECHNIQUES OF FOOD PRESERVATION

The course is designed for an over view of processing and preservation techniques used in food preservation. Age old methods for preservation are drying/dehydration and fermentation. Modem methodologies for preservation such as Pasteurization and Sterilization Food Irradiation Vacuum Packing Canning and Bottling were developed in last three decades and they have replaced most of the old practices thus avoiding losses. Food preservation aims to get a quality product in higher quantity, reduce the losses during processing, and get value-added products with enhanced shelf life. The basic principles of preservation include removal of moisture content and lowering of water activity, reduction of chemical reactions responsible for the self-decomposition of food, inactivation of enzymes, and microbial activity causing food deterioration. The course details are given in two blocks covering most aspects of preservation techniques.

Block I deals with **concept of food preservation and preparation of dehydrated products** in which two units are there. First unit deals with **concept of food preservation** while 2nd unit gives an idea about **preparation of various dehydrated products**

Block II deals with **preservation by using sugar, chemicals, salts and advanced preservation** which comprises of three units. third unit gives details about **preservation by using sugar** role of pectin in preserved foods stages in sugar cookery sugar concentrates and principles of gel formation several preserved foods explained. in fourth unit it is described how **preservation by achieved by using chemicals, salts and fermentation** and fifth unit explained about **preservation by advanced preservation technology**

Block III provides a comprehensive understanding of how microorganisms can both endanger and enhance food systems. From studying the causes of food-borne diseases to learning preventive systems like HACCP and appreciating the beneficial applications of microbes, this block bridges microbiology with food safety and public health.

BLOCK-I CONCEPT OF FOOD PRESERVATION AND PREPARATION OF DEHYDRATED PRODUCTS

Unit-I Concept of food preservation: Importance of food preservation, types of food spoilage by microorganisms and by enzymes basic principles of food preservation food preservatives- use of salt, acid, sugar, natural food preservatives and artificial preservatives starting a food preserving unit product promotion strategies and marketing skills.

Unit-II: Preparation of dehydrated products: Methods of drying & dehydration, different types of driers, freeze drying- lyophilisation, packing & storage Drying methods for the selected products -Rice, Sago, Wheat, Maida, Rice flakes, black gram dhal, green gram dhal, Horse gram dhal Roots and Tubers General tips with drying foods Preparation of salted, dehydrated, preserves (Traditional Indian varieties of chips, Papads, Khakharas, etc and Masala Powders, onion, garlic, ginger powder etc.).Hands-on experience: Drying of vegetables- peas, potato, carrot, French beans, Reconstitution of dried vegetables, drying & preparation of powders- garlic, ginger, spices mix etc.

Unit III : Preservation by using sugar: Role of Pectin in Preserved foods Stages in Sugar Cookery Sugar Concentrates – Principles of Gel Formation Hands on Experience: Preparation of Jam, Jelly, Marmalades, Sauce and Squash Preserves, Candied, Glazed, Crystallized Fruits, Toffee Evaluation of pH, Acidity and pectin quality Visit to Fruits and Vegetable processing industry

UNIT 1 CONCEPT OF FOOD PRESERVATION

Structure

1.0 INTRODUCTION

Human beings have engaged in substantial food preservation practices for thousands of years. It was essential to provide a year-round supply of food. With the development of the economy, food storage has grown in significance. Life now would not be feasible without the stockpiling of food. Early food preservation techniques included smoking, drying, and salting. Early man was aware of the utilization of ice and snow to preserve perishable goods. Agricultural produce fermentation has also been recognized since ancient times. Alcoholic beverages were traditionally made from barley, rice, and fruit liquids. Since 2,000 BC, fermented soybean products have been consumed in the East. Food preservation should also halt the biochemical degradation of tissues and the change of their cell contents. Heat, cold, drying, fermentation, radiation, and chemicals are used to accomplish this. Any one of these methods can also cause food to deteriorate. The method used should ensure that microorganisms are eliminated or hindered, biochemical attacks are reduced, and the food is still preserved.

Food preservation is the practice of treating and handling food in such a way as to stop or greatly slow down its spoilage (loss of quality, edibility, and nutritional value) caused or accelerated by microorganisms and to prevent food-borne illness while maintaining the food's nutritional value, texture, and flavor. Drying, spray drying, freeze drying, freezing, vacuum packing, canning, preservation in syrup, sugar crystallization, and food preservation are common ways to apply these techniques, Irradiation and adding preservatives.

1.1 OBJECTIVES:

After reading this unit you should be able to:

- know about food preservation;
- learn various methods of food preservation;
- know about types of food spoilage;
- study different types of food preservatives; and

• learn various scope of food preserving unit

1.2 METHODS OF FOOD PRESERVATION

The common methods of food preservation are as follows:

1. Asepsis: Keeping out microorganisms is known as asepsis.
2. Removal of microorganisms e.g., filtration, centrifugation.
3. Maintenance of anaerobic conditions, e,g., in a sealed, evacuated container.
4. Use of high temperatures e.g., pasteurization, oven drying, sterilization
5. Use of low temperatures e.g., refrigeration, cooling, freezing
6. Drying: it is the process of securing water with solutes, hydrophilic colloids, etc.
7. Using chemical preservatives that have been either added or created by microbes.
8. Irradiation.
9. Mechanical destruction of microorganisms, e.g., by grinding, high pressures, etc. (not used industrially).
10. A mix of two or more of the strategies mentioned above. One technique rarely works well on its own; most often, several are used in combination. For instance, meals that are preserved in canned form are heated up and sealed in an evacuated can.

Thermal Processing objectives

(i) Effect of thermal processing on microbial activity

(ii) Effect of thermal processing on enzyme activity

(iii) Effect of thermal processing on food quality

Thermal Processes

(i) Blanching: enzyme inactivation

(ii) Pasteurization: the destruction of pathogenic microorganisms

(iii) Sterilization: Complete destruction of microorganism

Food Drying/ Dehydration

(i) Heat requirement for vaporization

(ii) Heat transfer in drying

(iii) Drying and water activity

Cooling and freezing

(i) Air freezing

(ii) Plate freezing

(iii) Liquid-immersion freezing

(iv) Cryogenic freezing

1.1.5 Food Preservation using Chemicals

Chemical agents which serve to retard, hinder or mask undesirable changes in foods caused by microorganisms, enzymes in foods and chemical reactions.

(i) Salt and sugar preservation Ex.: High concentration of sugar – jams and jellies

High concentration of salt – pickles and sauces.

(ii) Other preservatives Ex.: Sorbic acid, Sodium or potassium metabisulphites which are colorless and sodium benzoate which is colored.

Other Emerging Techniques

(i) Modified atmosphere packaging (MAP)

(ii) Controlled atmosphere storage (CAS)

(iii) Genetic engineering

1.3 IMPORTANCE OF FOOD PRESERVATION

Food preservation uses a variety of techniques, such as drying, freezing, pickling, and irradiation, to reduce or eliminate food spoilage

Benefits of food processing and preservation include better nutrition, a longer shelf life, and more employment opportunities.

Any technique used to modify food in order to lower the number of undesirable microorganisms, increase its stability, and increase its safety margins makes the food more suited for human ingestion.

1.4 TYPES OF FOOD SPOILAGE BY MICROORGANISMS AND BY ENZYMES

Food spoilage commonly referred to as "an organoleptic change in food," can occur at any point in the food chain. This degeneration could be influenced by bacteria, naturally occurring enzyme activity, physical damage from insects, and other factors. Foods that spoil and undergo flavour, fragrance, or texture changes are spoiled. Spoiled food is a byproduct of harm or injuries that render it unfit for human eating. Food becomes deteriorated due to microbial activity, insect damage, physical harm, and enzymatic degradation. Depending on the quality features of the meal, all foods experience variable degrees of deterioration or spoilage, which may be physical, chemical, or biological? Foods go through physical and chemical changes that make them unsafe to eat or inedible as they deteriorate. All meals can be divided into one of the following three classes based on how easily or quickly they spoil:

Non-perishable foods:

As the name implies, these are foods that can be kept for at least a few months and do not go bad unless handled and stored carelessly. Cereals, legumes, sugar, and other non-perishable food items are examples.

Semi-perishable foods:

Semi-perishable foods, like non-perishable foods, can last for a few weeks or even a few months without showing any obvious signs of decomposition. Environmental variations, such as differences in temperature and humidity, have greatly altered these meals. Examples include foods derived from grains and pulses such as wheat flour, refined wheat flour, semolina, vermicelli, broken wheat, and bengal gramme flour (besan), as well as roots and tubers such as potatoes, garlic, some fruits such as apples and citrus fruits, as well as fats and oils.

Perishable foods:

These are the items with a very high-water activity (~~aw~~ a_w) that degrade quickly within a day or two unless specific preservation techniques are applied, such as all animal goods like milk and milk products, meat and meat products, fish, poultry, and eggs, as well as the majority of fruits and vegetables. The factors which lead to food spoilage are as below.

a) Microorganisms' development and behaviors, primarily those of bacteria, yeasts~~,~~ and molds

b) Food enzyme activities include enzymatic browning, for example.

c) Infestation by insects, parasites and rodents

d) Chemical modifications to food include, for example, the rancidity-causing chemical oxidation of fats and the non-enzymatic browning reaction.

e) Physical changes, or the damages caused by freezing or drying etc.

f) Presence of foreign bodies, and

g) Physical abuse i.e., contamination with chemical agents

Main causes of Food Spoilage:

- Growth of microorganisms like bacteria, yeast and molds
- Action of enzymes that usually found in food
- Additional causes of spoilage are non-enzymatic reactions like oxidation, mechanical damage like brushing, by rodents and insects.

Microbial food spoilage:

The primary cause of microbial food deterioration is that when the organisms multiply, they release their own enzymes into the liquid around them and absorb the byproducts of external digestion, which reduces the nutritional value of the meal itself.

Enzymatic food spoilage:

Activities of food enzymes are also responsible for causing deteriorative changes and spoilage for instance, enzymatic browning. The microbial enzymes hydrolyze fats to yield free fatty acids (FFA) and glycerol. Some fungi and bacteria secrete pectolytic enzymes causing rot which is characterized by the softening of the tissue due to their pectolytic action. The autolytic enzymes (self-digesting) do play an active role in the deterioration of meat, poultry and fish apart from the microorganisms. The psychotropic bacteria produce enzymes such as proteases, lipases and other enzymes. The proteases while hydrolyzing the milk proteins, impart a bitter flavor. The lipases are responsible for the rancid off-flavor.

1.5 BASIC PRINCIPLES OF FOOD PRESERVATION

1. Prevention or delay of microbial decomposition

a) By keeping out microorganisms (asepsis)

b) By removal of microorganisms, e.g., by filtration

c) By hindering the growth and activity of microorganisms, e.g., by low temperatures, drying, anaerobic conditions, or chemicals

d) By killing the microorganisms, e.g., by heat (pasteurization, sterilization) or radiation (radicidation, raddurization, radappertization)

2. Prevention or delay of self-decomposition of the food

a) By destruction or inactivation of food enzymes, e.g., by blanching

b) By prevention or delay of enzymatic action and purely chemical reactions, e.g., prevention of oxidation by means of an antioxidant (natural/synthetic)

3. Prevention of damage due to insects, rodents, animals, mechanical causes, etc.

1.6 FOOD PRESERVATIVES- USE OF SALT, ACID, SUGAR, NATURAL FOOD PRESERVATIVES, AND ARTIFICIAL PRESERVATIVES

A material or combination of substances that is added to food as a result of any step in its production, processing, storage, or packaging is referred to as a food additive. The phrase "chance contamination" is not included (WHO, 1965). This concept emphasizes the notion that a food additive is an intentional addition. **Chemical preservatives** are those food additives that are particularly applied to stop a portion of food from deteriorating or decomposing. These deteriorations may be brought on by dietary enzymes, bacteria, or merely chemical processes. One of the primary goals of using chemical preservatives is to prevent the development and activity of germs. By interfering with their cell membranes, enzyme function, or genetic pathways, preservatives can inhibit microorganisms. Other preservatives can act as antioxidants to prevent the oxidation of unsaturated fats, acidity neutralizers, and stabilizers to stop physical changes, firming agents, coatings or wrappers to prevent microbial growth, water loss, or undesirable microbial, enzymatic, and chemical reactions.

Sugar and Salt

These substances have a negative impact on microbes by lowering the water activity (a_w). In brines and curing solutions, as well as when applying it directly to food, sodium chloride is used. Only enough may be added to allow an acid fermentation to occur, or just enough to delay or halt the growth of microorganisms. According to reports, salt has the following effects: (1) it results in high osmotic pressure, which leads to plasmolysis of cells; (2) it dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells; (3) it ionizes to produce the chlorine ion, which is harmful to organisms. The amount of salt required to inhibit growth or harm the cell depends on the microorganism; (4) it reduces the solubility of oxygen in the moisture, (5) it sensitizes the cell against carbon dioxide, and (6) it interferes with the action of proteolytic enzymes. The relationship between the temperature and the concentration of NaCl is direct. The capacity of sugars to prevent organisms from accessing water and their osmotic impact are what give them their efficiency as preservatives. Examples of these sugars include glucose and sucrose. High sugar content foods like sweetened condensed milk, fruit sirups, jellies, and sweets are examples of foods that are preserved.

Significance of different preservatives

- ***Sodium chloride*****:** Antimicrobial, dehydrating agent, used as brine
- ***Sugar*****:** Preservation of foods due to the high osmotic pressure
- ***Sulfur dioxide*****:** Prevents the growth of undesirable microbes during wine making, prevents browning of dried and cut fruits

- ***Nitrate and Nitrite*****:** Color stabilizer in the curing of meat and antimicrobial in action
- ***Sorbic acid*****:** Sodium and potassium salts inhibit the growth of molds and yeast in cheese and bakery products, fruit juices, wines and pickles
- ***Acetic acid*****:** Vinegar (4% acetic acid) is used to preserve pickled vegetables, acetates of sodium, potassium and calcium are used to prevent ropiness and growth of molds
- ***Propionic acid*****:** Sodium and calcium salts are effective against molds and some bacteria; Controls *Bacillus mesentericus* causing ropy bread
- *Benzoic acid*: Active agent against yeast and bacteria, well suited for the preservation of acid foods such as fruit juices, carbonated beverages, pickles and sauerkraut
- ***Parabens*****:** Effective inhibitors of molds and yeast, they are alkyl esters of p-hydroxybenzoic acid; Methyl, ethyl, propyl and heptyl esters are used
- ***Epoxides*****:** Antimicrobial cyclic esters, used as preservatives—ethylene oxide and propylene oxide; to reduce load of microbes in spices
- ***Antibiotics*****:** Antimicrobial agents used in the control of bacteria in fish and poultry products; Chlorotetracycline and oxytetracycline
- ***Diethyl pyrocabonate*****:** Used as an antimicrobial agent in fruit juices, wines and carbonated beverages

1.7 STARTING A FOOD PRESERVING UNIT PRODUCT PROMOTION STRATEGIES AND MARKETING SKILLS.

With the moderate climate over the Indian subcontinent, there are no wide fluctuations in the availability of fruit and vegetables, and the need for food preservation has not been felt in India.

Scope

- The scope for expansion of food preservation market domestically and internationally is immense.
- The scope and significance of food processing are enormous, and a variety of techniques are employed to get various outputs. Numerous techniques, such as canning, freezing, dehydration, pickling, and irradiation, can be used to treat and preserve food.
- Cooking, which can be used to prepare food in many ways for consumption, is perhaps the most used form of food processing. Either at home or in a business environment like a restaurant or factory, anyone can cook.
- All the procedures needed to turn uncooked agricultural produce into wholesome food items are referred to as food processing and preservation. To guarantee accessibility to healthy, wholesome, and delectable foods at affordable prices, food processing, and preservation are essential.
- Food processing enhances the shelf life of food through various ways such as microorganism control, low-temperature storage, dehydration, and removal of oxygen. In order to appeal to consumers, it also modifies the nutritional content, flavour, and texture of food products.
- The processing of food is a significant sector of the Indian economy. About 15 million people

are employed by it, and it contributes about 10% of India's GDP.

- By 2022, the sector is predicted to grow significantly to a value of Rs. 2,58,000 crores. The food processing industry offers strong returns on investment and has a wide range of investment opportunities.
- The food processing sector in India faces a number of difficulties, including inadequate infrastructure, a skilled labour shortage, poor access to financing and raw materials, high energy costs, inadequate storage facilities, and limited market exposure.
- The growth of India's economy depends heavily on the food processing sector. By fostering a climate that would stimulate investments in infrastructure, research, innovation, and technology advancement, the sector needs to be incorporated into the nation's inclusive growth strategy.
- Additionally, the government ought to promote the growth of the food processing sector and raise public awareness of the value of processed foods. We can only hope that the sector will expand and help India's economy grow.

The requirement for establishing a food preserving unit is as follows

a) Use of a cost-effective packing system

b) Due to large production, there has been an alignment of quality management systems like ISO 9000, ISO 22000, and HACCP (Hazard Analysis Critical Control Point).

c) The chain of food supply has been seen to be fragmented, the handling of the post-harvest needs to be improved, Sorting, packaging, and storing after cleaning.

d) Food consumption has changed over time in response to demand, taste, lifestyle, level of living, and advancements in R&D production, processing, preservation, and storage.

e) Creation of a retail trade network with excellent and sanitary storage facilities.

Product Promotion strategies and marketing skills

Product Promotion strategies considered to promote goods and company as well in market environment. Consider drafting a thorough marketing strategy that will aid in defining and formalizing your marketing concepts and ideas. You can maintain focus and make sure that your marketing objectives are in line with your entire business goals and strategy by outlining your plans in writing. You may use it to create projects and deadlines and make sure your resources are being used properly and efficiently. Additionally, it will give bankers and lenders a clear picture of how you intend to maintain and expand your firm.

Write a thorough marketing plan for your food product and company using the eight components below as a reference.

1 **Executive Summary**

You should always write your executive summary last. It should succinctly summarizes and emphasize the most important ideas from each area of your marketing strategy. Your executive summary needs to be brief and not more than one page long.

2 **Market Research**

Examine the prospective customer base for your culinary item. Utilize a variety of primary research methods, including: - fieldwork, interviews, surveys, focus groups, experiments, and trials

- secondary research, including previous studies, journal publications, trade journals, and web data

3 Branding

To create a powerful brand, you must outline the fundamental principles of your business, such as your:

- a mission statement that outlines the main goals and priorities of your business
- positioning statement - identify your target market and how you want your brand to be perceived in the marketplace
- vision statement - specify your company's high-level goals for the future
- unique selling proposition (USP) - specify why customers should buy your product by stating what value

4 Target Market

Using the results of your market research, pinpoint the target market for which your product will be most valuable.

Everyone will not be a possible customer for your product, which is quite unlikely. Avoid attempting to sell to everyone. Analyze your data to demonstrate that your food product is in demand in your target market.

5 Competitors and Business Analysis

- Utilize the data you have obtained from your market research to identify and analyze your competitors.
- Compare the strengths, flaws, opportunities, and threats of your business to those of your rivals.
- Determine the competitive edge your business enjoys over its rivals.
- Determine the projected rate of sales growth for your food category over the next one to three years.
- Analyze your competitors' production capabilities and resources to see if they can satisfy existing and future food category market demand in your target market. If they do, you might want to adjust your target audience.
- Identify your USP, which will set your product apart from that of your competitors.

6 Marketing Action Plan and Strategy

Review your target market profile before developing a marketing strategy and action plan. Determine the most effective strategies for attracting potential customers to your business, piquing their interest and motivating them to buy your food product.

7 Marketing Goals

- Establish marketing goals that are realistic, quantifiable, and timely. Increased sales, increased brand recognition, the introduction of a new product, and the targeting of new markets or consumers are a few examples of marketing aims.
- Identify the KPIs you'll use to gauge the success of your marketing initiatives. For instance, you might choose to monitor website traffic, social media activity, and referrals if your marketing

goal is to raise brand awareness.

- To be sure you're getting good results from any marketing activity, measure and document it beforehand, during, and after. If not, you now have the chance to enhance your marketing campaigns and assist with future planning

8. Financial Projections

Include the following current financial data to demonstrate financial viability over a given time period (usually a 12-month timeframe) in your financial projections

1.8 LET US SUM UP

In this unit, we have learnt about what is preservation along with various methods of preservation. Preservation is mainly important to prevent microbial entry into the food which causes food spoilage. Spoilage is based on the quality characteristics of the food itself as well as its susceptibility to getting spoiled. Preservation helps to reduce enzymatic spoilage as well as the self-deterioration of food through various chemical reactions. Various methods of preservation are discussed briefly in this unit.

1.9 CHECK YOUR PROGRESS

Note: Use the spaces given below for your answers.

1) What is the requirement for establishing a food-preserving unit?

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2) What are the principles of food preservation?

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3) Discuss briefly the methods of preservation.

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4) Enlist different types of preservatives used in food preservation.

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UNIT-II PREPARATION OF DEHYDRATED PRODUCTS

Structure

2.0 Introduction

2.1 Objective

2.2 Methods of drying & dehydration

2.3 Different types of driers, freeze drying- lyophilization,

2.4 Packing & storage Drying methods for the selected products -Rice, Sago, Wheat, Maida, Rice flakes, black gram dhal, green gram dhal, Horse gram dhal Roots and Tubers

2.5 General tips with drying foods Preparation of salted, dehydrated, preserves (Traditional Indian varieties of chips, Papads, Khakharas etc and Masala Powders, onion, garlic, ginger powder etc.).

Hands-on experience: Drying of vegetables- peas, potato, carrot, French beans, Reconstitution of dried vegetables, drying & preparation of powders- garlic, ginger, spices mix etc.

2.6 Let Us Sum Up

2.7 Check Your Progress

2.0 INTRODUCTION

One of the earliest techniques for preserving fruits and vegetables is drying. It is currently a flexible and common approach in the food industry and a persistently fascinating topic in food research. Due to the high energy need of the process (caused by the low thermal efficiency of dryers), drying is a crucial step in the processing of dehydrated products. Fruits and vegetables are dried primarily to remove moisture up to a point when microbial spoilage and deterioration chemical reactions are significantly reduced. In addition to preserving the product, dried foods are less expensive to package, handle, and transport due to their less weight and reduced bulk. The majority of food products are also dried for better milling or mixing properties during subsequent processing.

2.1 OBJECTIVES

After reading this unit you should be able to:

- know about methods of drying and dehydration;
- learn various methods of food drying;
- know about types of driers;
- study drying of various types of cereals and pulses
- study different types of salted, dehydrated, preserves

2.2 METHODS OF DRYING & DEHYDRATION

The number of microorganisms that are reduced by heat delivered during a drying process depends on the types and numbers of microorganisms that were initially present as well as the drying method used. All yeasts and the majority of bacteria are often destroyed, however, spores of bacteria and molds, as well as vegetative cells of a few species of heat-resistant bacteria, frequently survive. As we'll see later, unfavorable drying conditions might even promote the growth of microbes.

Solar Drying

Solar drying is only possible in hot, dry locations and on a few types of fruit, including raisins, prunes, figs, apricots, nectarines, pears, and peaches. On trays, the fruits are dispersed and may be turned while drying. Sun drying is also an option for cereals like rice and fish.

Drying by Mechanical Dryers

The majority of artificial drying techniques include either passing heated air over the food to be dried or passing the food through air with a set relative humidity. A variety of equipment is utilized in some operations for controlled air circulation and air reuse. The simplest drier is the evaporator or kiln, which is occasionally used in farm homes. Here, the food is dried by natural draught caused by the rising heated air. Systems that use forced-draft drying circulate hot air across the food, typically in tunnels. Liquid foods, like milk, juices and soups, may be evaporated by using relatively low temperatures and a vacuum in a vacuum pan or similar device, drum-dried by passage over a heated drum, with or without vacuum or spray-dried by spraying the liquid into a current of dry, heated air.

Freeze Drying

Freeze drying, often referred to as lyophilization or cryodesiccation, is a low-temperature dehydration technique that involves freezing the product, lowering the pressure, and then sublimating the ice. A liquid object changes states more smoothly than a solid (ice) entity. It comprises removing the water from the ice and heating it (either by radiation, conduction, or even both) until the liquid evaporates, leaving only the solids or dry components of the original liquid. Drying of materials is required at lower pressures and triple-point temperatures. For a variety of items, including meats, poultry, shellfish, fruits, and vegetables, freeze drying—or the sublimation of water from a frozen food by use of a vacuum and heat—is being used. Foods with low sugar content that are frozen in thin layers can be dried without a vacuum by sublimating moisture while a dry carrier gas passes over them.

Drying During Smoking

Food moisture removal aids in preventing bacterial and fungal growth, which could harm meals that have been preserved. Smoking is a method of drying that also flavours the food (often meat products), and smoke deters insects that transport bacteria while the food is drying. Food can be smoked using two different techniques: **hot smoking** and **cold smoking**. Modern electric kilns or the smokehouse can be used for hot smoking, which is typically done for a brief length of time, only long enough to cook the meat. ...

Hot smoking: Hot smoking is subjecting food to heat and smoke in a controlled setting, such a smoker oven or smokehouse. It calls for the employment of a smoker, which generates heat from a heated element inside the smoker, a heated element on the stovetop, or an oven. Food is hot smoked by cooking and flavoring with wood smoke at the same time. 52 to 80 °C (126 to 176 °F) is typically the range in which hot smoking takes place. Food is fully cooked, moist, and tasty when smoked at these temperatures. Foods may shrink excessively, buckle, or even split if the smoker is allowed to reach temperatures higher than 85 °C (185 °F). Because both moisture and fat are fried while smoking at high temperatures, the yield is likewise decreased.

Cold Smoking: In contrast to hot smoking, cold smoking involves keeping the food uncooked throughout the procedure rather than cooking it. Cold smoking is commonly carried out in smokehouses with temperatures ranging from 20 to 30 °C (68 to 86 °F). Foods get a smoky flavor at these temperatures while still being largely wet. Foods should be completely cured before cold smoking because cold smoking does not cook meals. Items like cheese or almonds can be cold-smoked to add flavor, in addition to meats like chicken breasts, beef, pork chops, salmon, scallops, and steak.

Other methods of smoking are as follows

Liquid Smoke: Liquid smoke, a substance made from smoke components in water, is sprayed or dipped onto foods.

Smoke-roasting: Any procedure that combines the characteristics of roasting with smoking is referred to as smoke-roasting. Barbecuing or pit-roasting are other names for this smoking technique. It can be done in a smoker that can reach temperatures exceeding 121 °C (250 °F), a closed wood-fired oven, a barbeque pit, or a standard oven by spreading a pan of hardwood chips on the oven's floor so that they can smoulder and create a smoke-bath. This type of smoking is frequently referred to as "barbecuing," "pit baking," or "pit roasting" in North America.

Warm smoking: Foods are heated at temperatures between 77 and 104 °F (25 to 40 °C).

Other Methods of drying

Electronic heating: Electronic heating has been suggested for the removal of still more moisture from food already fairly well dried. Foam-mat drying, in which liquid food is whipped to a foam, dried with warm air, and crushed to a powder, is receiving attention, as is pressure-gun puffing of partially dried foods to give a porous structure that facilitates further drying. Tower drying in dehumidified air at 30° C or lower has been successful with tomato concentrate, milk, and potatoes.

A consideration of the proper control of dehydration includes the following factors.

1. The temperature employed. This varies with the food and the method of drying.

2. The relative humidity of the air. This, too, is varied with the food and the method of drying and also with the stage of drying. It usually is higher at the start of drying than it is later.

3. The velocity of the air.

4. The time of drying.

Improper control of these factors may cause case-hardening resulting from more rapid evaporation of moisture from the surface than diffusion from the interior, with a resulting hard, horny, impenetrable surface film that hinders further drying.

The Value of Drying

- Enables grain to be stored for a long time without deteriorating
- Enables year-round, continuous product supply
- Allows for an early harvest, minimizing free field damage and shattering loss
- Enables farmers to produce higher-quality goods
- Makes things accessible outside of peak times

Drying theory

- The removal of moisture from a product by convection

- water contents are expressed as moisture contents, and they gain or lose moisture depending on the meteorological circumstances
- The differential in vapor pressure between the atmosphere and the product determines whether moisture migrates into or out of that product.
- When grain vapor pressure exceeds air vapor pressure, moisture is transferred from grain to atmosphere.
- If the air vapor pressure is higher than the vapor pressure of the grain, the grain will absorb atmospheric moisture.

Drying rate periods: Divided into 3 periods

 Constant rate period

 First Falling rate period

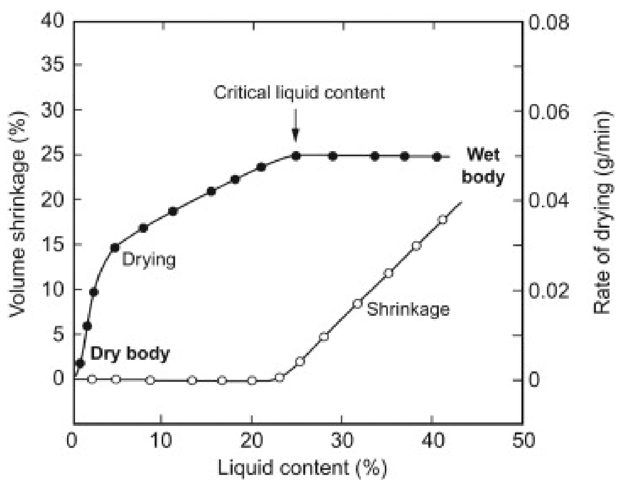
 Second falling rate period

Constant rate period

The rate of moisture migration from a product's inside to its exterior is equal to the rate at which water evaporates off the surface. This process continues until threshold moisture content is achieved. When constant rate drying stops and falling rate drying begins, the moisture content of the product reaches this point. For agricultural products, this phase is quite brief. Sand and washed seeds are dried during the constant rate period.

Falling rate period

The falling rate period is reached when the droplet surface is no longer saturated, and drying is controlled by internal mass transfer of the volatile solvent to the surface. The particle surface forms a shell or crust, and the droplet's diameter shrinkage is low or constant.



Source:https://www.sciencedirect.com/topics/engineering/falling-rate-period

The movement and distribution of moisture within grains' interiors regulates the drying process, which is how most agricultural goods are dried. Controlled by: Removal of moisture from the surface Moisture migration from the core of grains to the top surface as a result of water vapor diffusion it is divided into two periods

 First falling rate period

 Second falling rate period

First falling rate

- Unsaturated surface drying
- Fraction of wet surface reduces to zero, marking the end of the initial decreasing rate
- drying rate decreases as wet surface area declines

Second falling rate

- Sub surface evaporation takes place & it continues until the equilibrium moisture content is reached

Mechanism of drying process

- Movement of moisture takes place due to
- Capillary flow – Liquid movement due to surface forces
- Liquid diffusion – Liquid movement due to difference in moisture concentration
- Surface diffusion - Liquid movement due to moisture diffusion of the pore spaces
- Vapour diffusion – vapour movement due to moisture concentration difference
- Thermal diffusion - vapour movement due to temperature difference
- Hydro dynamic flow – water and vapour movement due to total pressure difference

2.3 TYPES OF DRIERS

Thin layer drying

Process in which all grains are fully exposed to the drying air under constant drying conditions i.e. at constant air temperature & humidity it utilizes up to 20 cm thickness of grain bed as thin layer. All commercial dryers are designed based on thin layer drying principles

Represented by Newton's law by replacing moisture content in place of temperature

$M\text{-}Me/Mo\text{-}Me = e^{-K\theta}$

M – Moisture content at any time θ, % db

Me- EMC, %db

Mo – Initial moisture content, %db

K – drying constant

θ - time, hour

Deep bed drying

- All grains are not fully exposed to the same condition of drying air
- Condition of drying air changes with time and depth of grain bed
- Rate of airflow per unit mass of grain is small

- Drying of grain in deep bin can be taken as sum of several thin layers
- Humidity & temperature of air entering & leaving each layer vary with time
- Volume of drying zone varies with temp & humidity of entering air, moisture content of grain & velocity of air

Deep bed drying characteristics at different depths

Continuous flow dryer

- Columnar type dryer in which wet grains flow from top to the bottom of the dryer
- Two types
- Mixing
- Non-mixing

Mixing

- Grains are diverted in the dryer by providing baffles
- Use low air flow rates of 50-95 m3/min/tonne
- Zig-zag columns enclosed by screens are used to achieve mixing
- High drying air temperature of 65°C is used

Continuous flow dryer (Mixing type)

Baffle dryer

- Continuous flow mixing type dryer
- Consists of receiving bin, drying chamber fitted with baffles, plenum fitted with hot air inlet
- Baffles are fitted to divert the flow & also for mixing
- Grain fed at the top & move downward in a zig-zag path where it encounters a cross flow of hot air
- Bucket elevator is used to recirculate the grain till the grain is dried to desired moisture level
- Uniformly dried product is obtained

Mixing type baffle dryer

Non-mixing

- Grains flow in a straight path
- Baffles are not provided and drying takes place between two parallel screens
- High airflow rates can be used
- Drying air temp. of 54°C is used

Continuous flow dryer (non-mixing)

Recirculatory Batch dryer

- Continuous flow non mixing type
- Consists of 2 concentric circular cylinders, set 15-20 cm apart
- Bucket elevator is used to feed & recirculated the grain
- Centrifugal blower blows the hot air into the inner cylinder, acts as a plenum
- Grain is fed at the top of the inside cylinder; comes in contact with a cross flow of hot air
- The exhaust air comes out through perforations of the outer cylinder
- Grain is recirculated till it is dried to desired moisture content
- Drying is not uniform as compared to mixing type
- Recirculating batch dryer

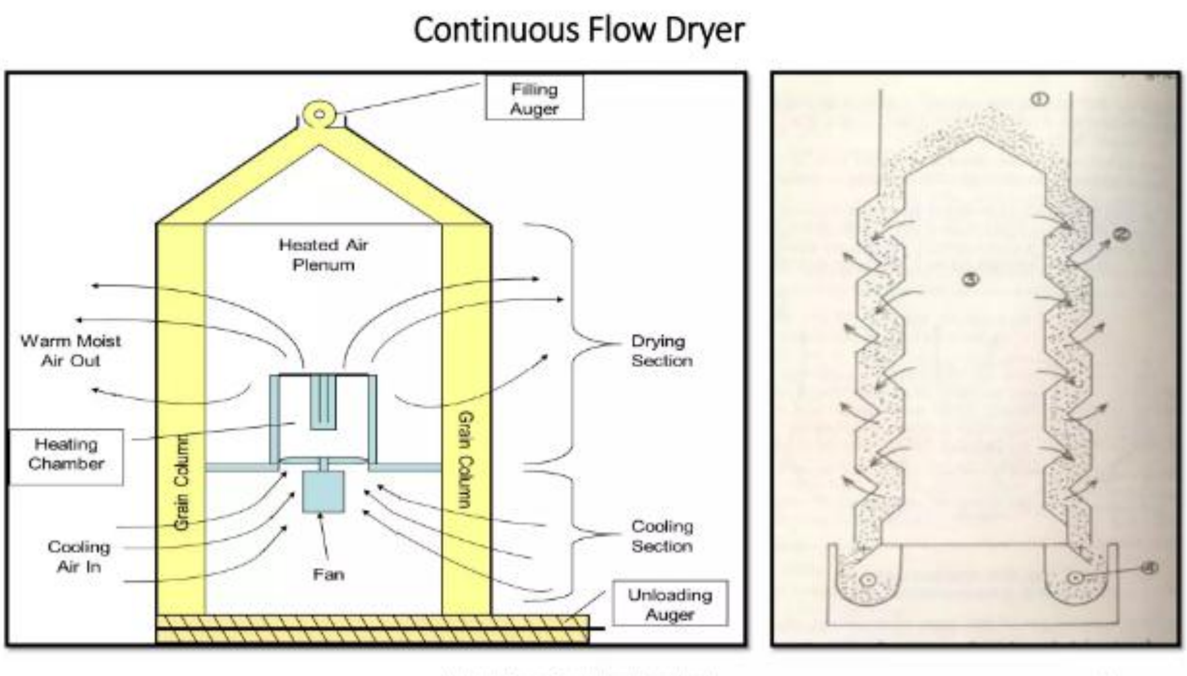
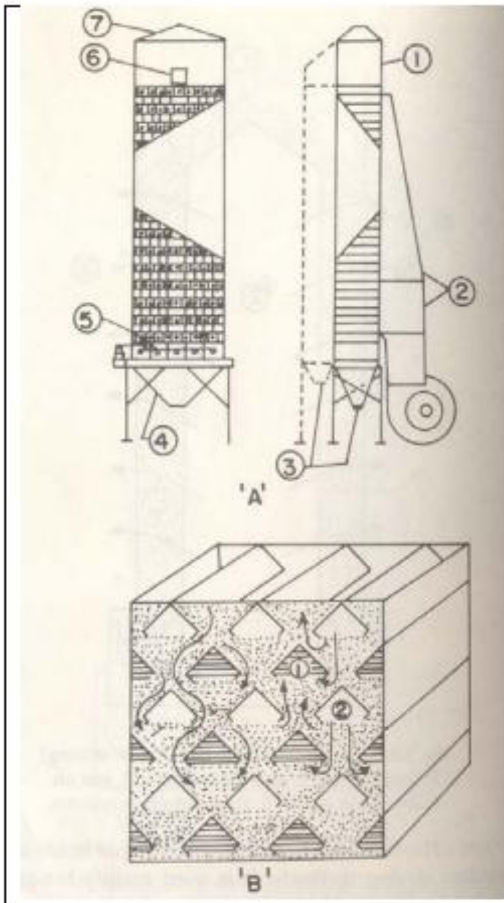


Fig 2.1Continuous flow dryer LSU dryer

- Developed at Louisiana state university (LSU). It is a continuous mixing type dryer
- Developed specifically for rice to ensure gentle treatment, good mixing & good air to grain contact
- The instrument consists of a rectangular chamber, holding bin, blower with duct, grain discharging mechanism and air heating system
- Layers of inverted V-shaped channels are installed in the drying chamber; heated air is introduced through these channels at many points
- Alternate layers are air inlet & outlet channels; arranged one below the other in an offset pattern
- Inlet port consists of few full-size ports & two half size ports; all ports are of same size arranged in equal spacing

- Ribbed rollers are provided at the bottom of drying chamber for the discharge of grain (capacity varies from 2-12 tonnes, air flow rate is 60-70 m3/min/tonne, air temp. is 60 &85°C for raw & parboiled paddy)
- Uniformly dried product can be obtained
- Can be used for different types of grain
- Only limitation is high capital investment

LSU Dryer



1. Garner
2. Duct
3. Dry material outlet
4. Hopper
5. Continuous flow
6. Door
7. Roof

Fig 2.2 LSU Dryer

LSU Dryer

Tray driers

- In tray dryers, the food is spread out, generally quite thinly, on trays in which the drying takes place.
- Heating may be by an air current sweeping across the trays, or heated shelves on which the trays lie, or by radiation from heated surfaces.
- Most tray dryers are heated by air, which also removes the moist vapours.

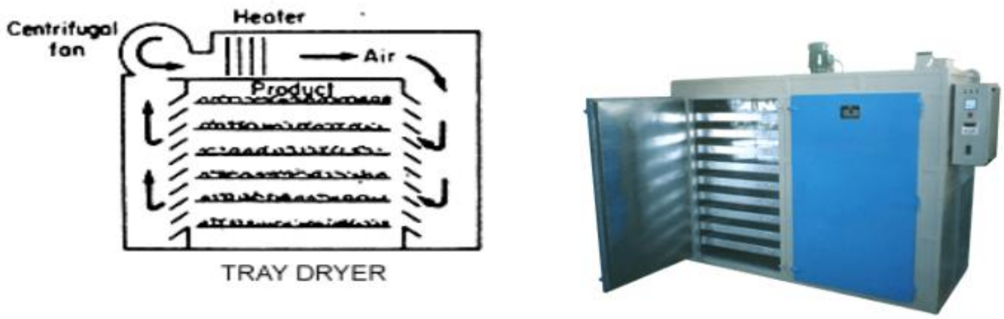


Fig 2.3 Tray Dryer

Fluidized Bed Dryers

In a fluidized bed dryer, the food material is maintained suspended against gravity in an upward-flowing air stream.

Heat is transferred from the air to the food material, mostly by convection

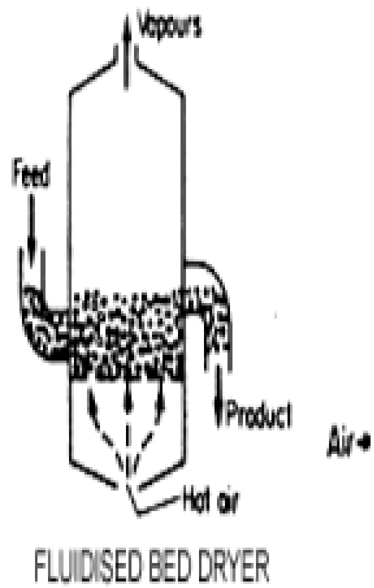


Fig. 2.4 Fluidized Bed Dryers

Pneumatic Dryers

- In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the
- Velocity and turbulence of the stream maintaining the particles in suspension.
- Heated air accomplishes the drying and often some form of classifying device is included in the equipment.
- In the classifier, the dried material is separated, the dry material passes out as product and
- The moist remainder is recirculated for further drying

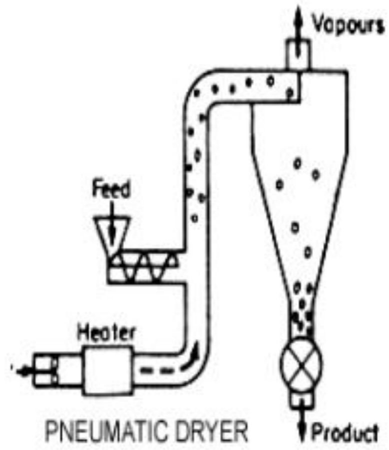


Fig 2.5 Pneumatic Dryers

Rotary Dryers

- The foodstuff is contained in a horizontally inclined cylinder through which it travels, being
- Heated either by airflow through the cylinder or by conduction of heat from the cylinder walls.
- In some cases, the cylinder rotates and in others the cylinder is stationary, and a paddle or
- The screw rotates within the cylinder conveying the material through

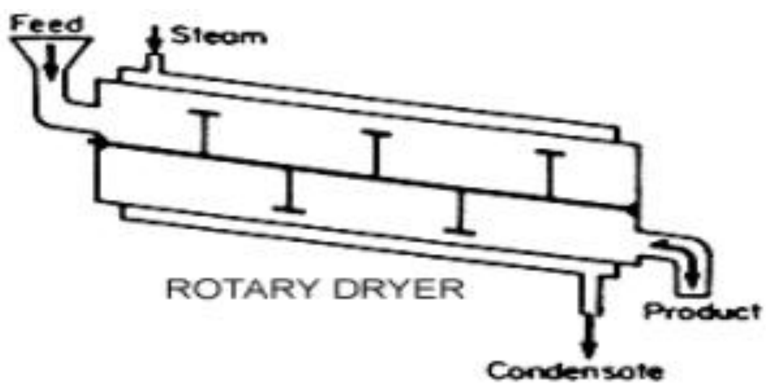


Fig 2.6 Rotary Dryers

Freeze drying- lyophilization

Freeze drying, or the sublimation of water from a frozen food by means of a vacuum plus heat applied at the drying shelf, is being used for a number of foods, including meats, poultry, seafood, fruits, and vegetables. Frozen thin layers of foods of low sugar content may be dried without vacuum by sublimation of moisture during the passage of dry carrier gas.

2.4 PACKING & STORAGE DRYING METHODS FOR THE SELECTED PRODUCTS -RICE, SAGO, WHEAT, MAIDA, RICE FLAKES, BLACK GRAM DHAL, GREEN GRAM DHAL, HORSE GRAM DHAL ROOTS, AND TUBERS GENERAL TIPS WITH DRYING FOODS

Farmers store grain all over the world, whether in hot or cold climates, more developed or less developed nations; they may store it in granaries, pits or earthen pots, either in bulk or in a moderately sophisticated elevator; the primary goal of storage is simply to prevent grain quality degradation; the management goal during the storage period is to reduce metabolic activity to such a low level that the grain mass is sufficiently stable with minimal change in composition.

Drying of cereals: a) Wheat: Wheat is classified into two groups: hard and soft. Hard wheat is higher in protein compared to soft wheat. Wheat is classified into two groups: hard and soft. Hard wheat is higher in protein compared to soft wheat. Wheat is classified into two groups: hard and soft. Hard wheat is higher in protein compared to soft wheat.

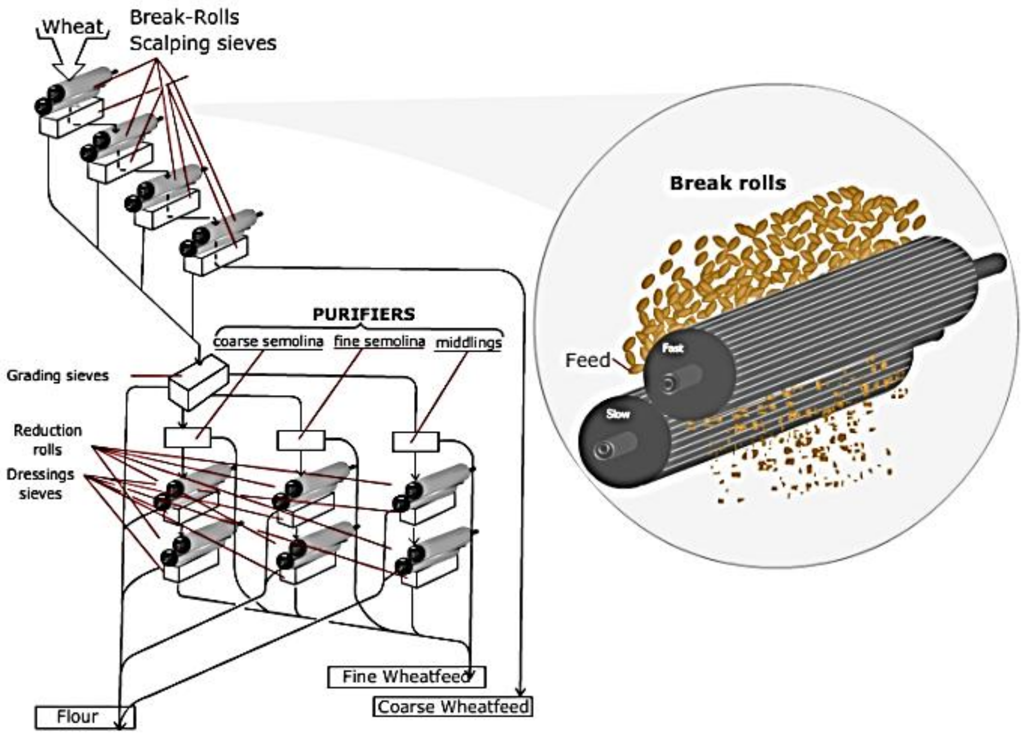


Fig 2.7 Wheat milling (Source [www.iaritopper.com)](http://www.iaritopper.com)

Maida/refined flour:

The finest sort of wheat flour, refined flour is used to make your favourite foods like pizza, bread, samosas, kachoris, puris, cakes, and biscuits. It has a high-calorie content but little nutritional value. The glycemic index of refined flour, often called maida in India, is higher than that of wheat flour. The endosperm, the starchy white portion of the grain, is used to make maida. The endosperm and germ are separated from the bran, which is then refined by passing through an 80-mesh-per-inch (31-mesh-per-centimeter) sieve.

Various flour types and their uses

- Flour, all-purpose. Anything is best used for
- The Hard Flour. The best uses are for bread, buns, and donuts.
- The cake flour. Tender cakes and pastries are what it is best utilised for.

- Whole-wheat flour. Best used for: thick cakes, bread, and cookies.
- Rice flour; Noodle flour; Cooking flour.

b) Rice:

Rice (*Oryza sativa*, Linn.) is one of the oldest and most important food crops of the world. It is a staple food for more than half of the World's population. Rice belongs to the Gramineae or grass family and the tribe *Oryzeae*. Rice is a semi-aquatic plant that can thrive under flooded soil conditions.In modern rice milling the steaming is done separately using a steaming unit. The steam is produced usually from a boiler unit under pressure. The soaked paddy is then dried. In modern rice mills usually LSU driers with hot air from steam-heated exchangers are used for drying.

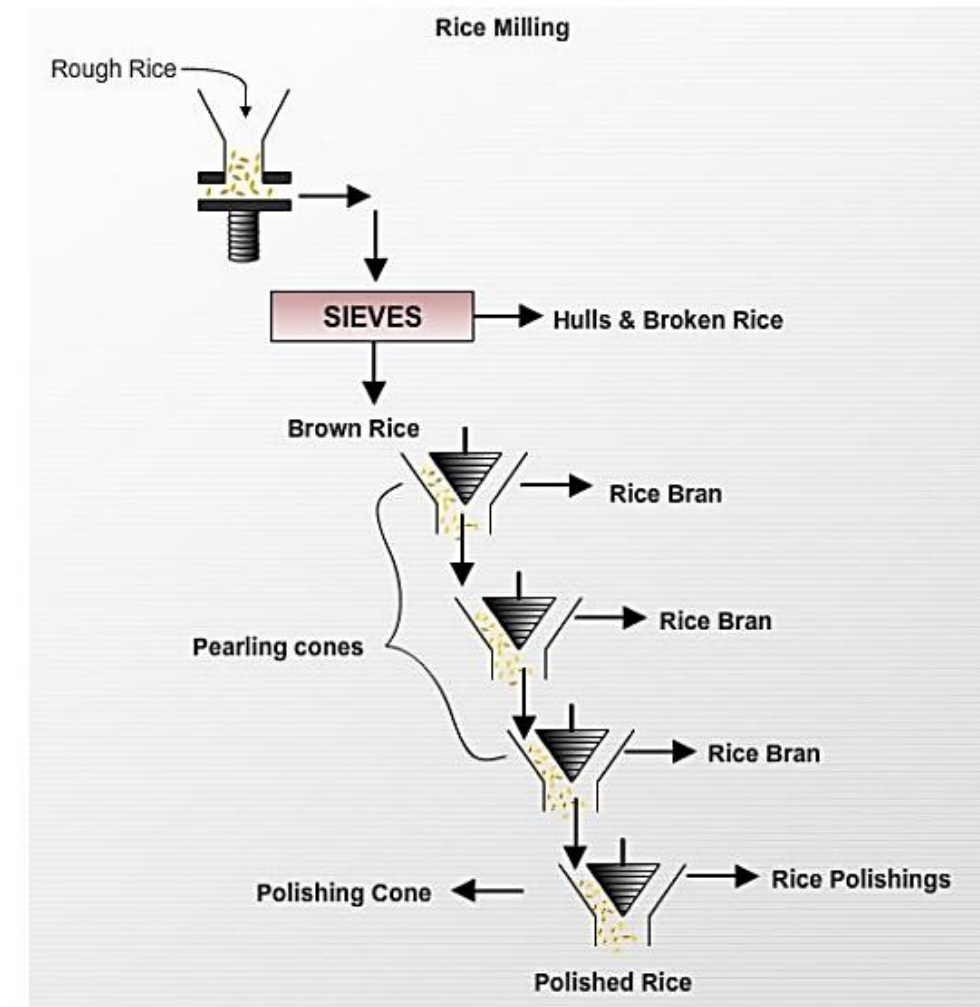


Fig 2.8 Process of rice milling (Source [www.iaritopper.com)](http://www.iaritopper.com)

Flaked/Rough rice

Parboiled rice is used to make flakes of rice. To soften the kernel, paddy is first soaked in water for two to three days (or heated water between 70 and 80 degrees for 20 minutes). After cooking, the water is removed, the paddy is heated in a shallow clay jar to between 250 and 275 degrees Celsius until the husk splits open, and then it is pounded with a wooden pestle and heavy iron rollers to flatten the rice kernel and remove the husk. Winnowing removes the husk.

Sago:

The starchy root crop known as cassava (*Manihot esculenta Cralztz*) is a staple meal used mostly in underdeveloped nations. Around 500 million people and more around the world eat the leaves and root tuber, which are both edible. Tapioca refers to the root tuber. The processed edible starch that is derived from tapioca and sold as sago (saboodana) comes in the form of tiny globules or pearls.

Pulse drying:

Pulse seeds are also sources of other nutritionally important materials, such as vitamins and minerals. Milling of pulses is the removal of outer husk/hulls and splitting the grain into two equal halves. The husk/hull is more tightly held by the kernel of some pulses poses problems. The alternate wetting and drying method are used to facilitate the de-husking and splitting of pulses.

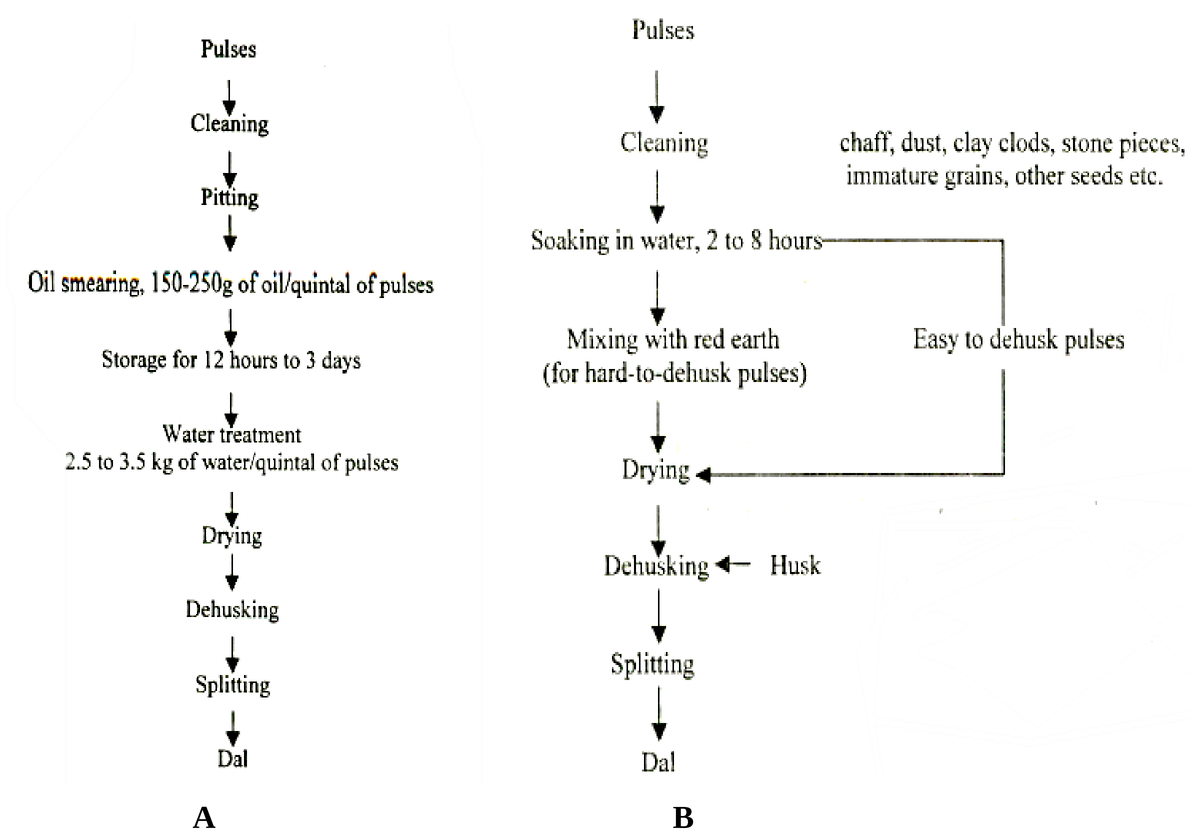


Fig. 2.9 Dry and wet milling of pulses (IGNOU study material)

Pulses can be divided into two general categories according to the difficulty faced in dehusking riz. (i) hard-to-dehusk pulses namely arhar, urad and moong and (ii) easy-to-dehusk pulses namely channa (Bengal gram), masoor (Lentil), and field pea.

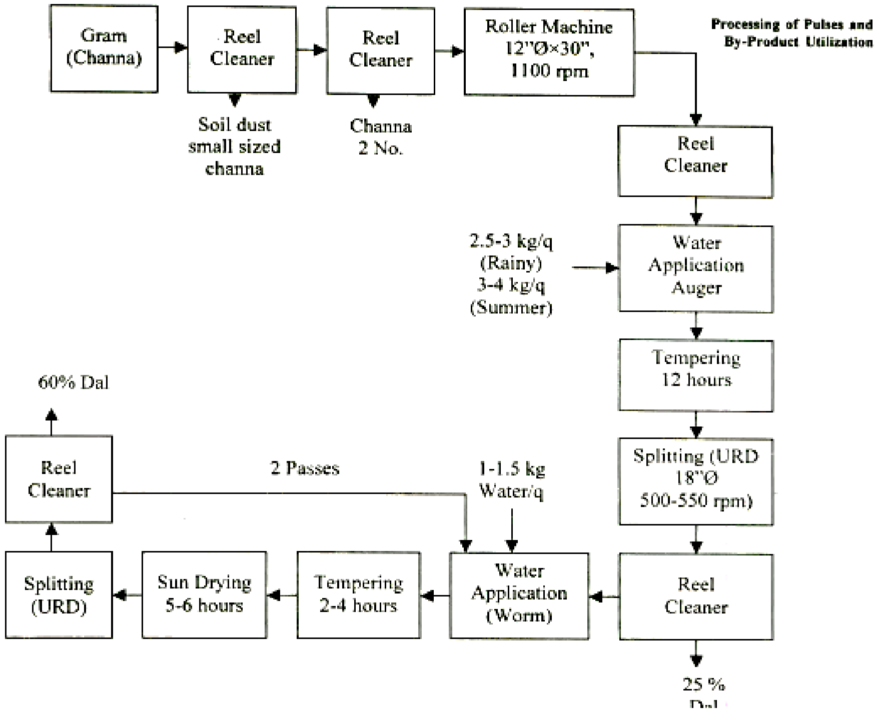


Fig 2.10 Processing of Bengal gram

2.5 PREPARATION OF SALTED, DEHYDRATED, PRESERVES (TRADITIONAL INDIAN VARIETIES OF CHIPS, PAPADS, KHAKHARAS ETC, AND MASALA POWDERS, ONION, GARLIC, GINGER POWDER ETC).

Dried foods are preserved as a result of the lower moisture content. It is conveniently portable. Indian delicacies like **chips, Papads, Khakharas,** onion, garlic, ginger, and curry powders are preserved by sun drying. **Preparations of such salted and dehydrated, preserves are as below-**

Chips: Potato Chips is one of such value-added products which has a great potential as this is considered as one of the traditional foods of India. Only two potato-based snack foods—chips/wafers and French-fried potatoes—represent more than 42% of all processed potato-based products worldwide as the primary value-added products of potatoes**.**

Manufacturing Process: The potatoes are carefully cleaned under running water before being peeled using an abrasive potato peeler. Water jets are used to remove the peelings. After trimming, they are submerged in water to stop browning. After that, slices (1.7-1.85 mm thick) are created using a cutting machine. If the successive steps of blanching take a long time, the slices are once more submerged in cold water. To prevent oxidation, slices are then stored in water containing 0.05% potassium metabisulphite. Slices are spread out on trays at a rate of 4.88 kg to 7.30 kg per square metre of tray area and blanched for 3 to 5 minutes in boiling water. After being blanched, the chips are ~~D-Watered~~ dewatered to remove excess water before being cooked in edible oil for 3–4 minutes at 180–240°C. The fried potato wafers are then placed on a sieve to drain excess oil, allowed to cool, and other ingredients such salts and a spicy mixture are sprayed on using a batch flavouring machine to the desired taste. After cooling, potato chips are packaged in plastic bags.

Papads: Papad is just the name for the thin Indian wafer, often known as a cracker or flatbread.

Typically made from dried pulses, papad can be roasted or fried. To improve both organoleptic and nutritional qualities, the papad's fundamental ingredients can include grain flour, pulse flour, soy flour, spice mixtures, chemical mixtures, and various vegetable juices. North Indian and South Indian papad are the two original varieties of papad. They are available in a variety of shapes and sizes, including tiny, large, roasted, khakra, and many others.

Manufacturing Process: Any papad must first have its dough prepared. To make the unique regional papad, the dough also has flavours like salt and peanut oil. Another essential element for a tasty papad is baking soda. The dough is formed into a circular, thin flatbread and typically dried in the sun. Papads can be roasted over an open flame, deep-fried, toasted, or microwaved.

Some of benefits are as follows

- Papad is a tasty appetiser and a healthy source of fibre.
- Papad that has been roasted or grilled aids in absorbing the fatty substances from the mouth and throat.
- Papad should be consumed in moderation to avoid becoming the cause of acidity.
- Papad has an extremely high salt content, making it unwise for those with hypertension.
- Lentils are used to make papads, which makes them gluten-free, high in protein, and low in fat.

Khakharas

Khakhara is a thin cracker popular in western Indian cuisines such as Gujarati and Rajasthani, particularly among Jains. Mat bean, wheat flour, and oil are used to make it. Typically, it is offered during breakfast. Khakhara is prepared with a number of different ingredients, including methi (fenugreek), jeera (cumin), bajri, pudina, garlic, and ajwain, among others. A sweet kind of khakhra is mungdi.

Manufacturing Process: The dough is rolled out into thin sheets to form Khakhara. Round shapes are cut out of the sheets. To completely remove the moisture level, they are first cooked on the Hot Plate and then roasted in the roasting apparatus. Khakhra that has been properly packed has a longer shelf life. Khakhara is made with the following machines:

1. Dough Making Machine: To mix flour, salt, and water to make the dough for Khakhara.
2. A Khakhara extruder is used to extrude the dough into tiny dough balls that are then rolled into thin sheets.
3. Sheet Making & Cutting Machine: To create the necessary thickness of very thin dough sheets and cut them into rounds.
4. Hot Plate: To bake and cook the khakhara till it is golden.
5. Roasting Device: To roast the baked Khakhara in order to lower its moisture level and get it ready for packaging.
6. Vacuum Packaging Equipment the Khakhra into appropriate printed vacuum-sealed packs.

Masala Powders

Blends of various Spices are called masalas. A spice can be any vegetable substance that is primarily used to flavour, colour, or preserve food. It can also be a seed, fruit, root, bark, berry, or bud. By geography and taste preference, a masala's precise ingredients might vary greatly. For instance, masala can be whole or ground spices, powerful or weak, bland or harsh, and dry or moist. Indian chefs have perfected the art of timing the roasting of spices, unleashing different aromas from the same spices depending on how long they are roasted. The manner in which a spice is made can also influence it.

Dry Masala: In Northern India, a masala is made of dry spices that have been ground into a powder that is resistant to spoilage and is claimed to improve with age.

Wet Masala: In Southern India, a masala is made with fresh or green spices that are blended with liquids like water, lime juice, coconut milk, or vinegar to create a paste that is only briefly edible.

There are various types of masala powder available in Indian market such as Chaat Masala, Sambar Masala, Pav Bhaji Masala, Garam Masala, Goda Masala, Pani Puri Masala, Kitchen King Masala, Thandai Masala Powder, Meat Masala, Rasam Powder, Kesari Milk Masala, Punjabi Chole Masala, Shahi Biryani Masala, Tea Masala Powder, Jaljeera Masala, Tandoori Masala, Fish Curry Masala, Chicken Masala, Pickle Masala, Curry Powder

Manufacturing Process: 1. Cleaning-It is a very primitive process of producing spices, involving the physical cleaning of unground spices to remove contaminants like stone, dust, and filth.

1. Drying- The quality of the spice powder can rely on how well-dried the spice was, therefore after cleaning and laundry, expose them to light so they can dry. Lack of proper laundry and cleaning will encourage the growth of bacteria that can contaminate food.
2. Roasting- After being dried, spices are put through the roasting process, which is crucial because it helps produce spice powder with a pleasing scent, colour, and flavour.
3. Grinding- The spices are pulverised using a grinding machine to create powder.
4. Grading- The grading process may be based on the inclusion and proportion of spices in relation to the raw materials used. It may also be influenced by the type of spices (flavour), as well as their size, shape, density, and colour.
5. Sieving- Make sure the mesh size of the spice powder is constant.
6. Spice packaging- Your favourite foods benefit greatly from the flavour that seasoning and spices bring. However, for them to work their magic, they must be fresh, so proper packing is essential.

Ginger powder: Ginger is first scrapped to remove skin and then washed so as to remove dirt. Then it is cut to small pieces so that it can be ground easily into a paste in a mixer and then dried/dehydrated to remove moisture and packed in airtight container

Garlic powder: peeled garlic in a grinder along with some water so as to get smooth texture as paste and then dried to remove moisture and packed in airtight sealed container

Curry Powder: The most popular of all spice blends or mixes is curry powder, which occasionally contains 20 or more spices and is made to influence the distinctive flavour of an Indian curry, which is loved by people all over the world. A clear trend today is towards employing spices primarily in powdered form in many combinations of curry powders, even if freshly ground masalas (mixed curry spices are preferred to powdered masalas) are favoured due to the lack of domestic labour. For the preparation of a range of veggie and non-vegetarian food products, curry powder, chilli powder, turmeric powder, spices powder, etc. are heavily used.

Hands-on experience: Drying of vegetables- peas, potato, carrot, French beans, Reconstitution of

dried vegetables, drying & preparation of powders- garlic, ginger, spices mix, etc.

2.6 LET US SUM UP

In this unit, we have learnt about the methods of drying and dehydration. Different types of driers used for cereals and pulse processing are discussed briefly. Pulses milling viz. wet and dry method. In dry method, it is the oil that loosens husk while in the wet method, it is water that dilutes gum in between the husk and kernel which makes it easy to dehusk pulses. In wet method, the cooking quality of dal is affected. Due to this, the dry method of milling is mostly practiced in country.

2.7 CHECK YOUR PROGRESS

Note: Use the spaces given below for your answers.

1) What do you mean by pulse milling?

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2) How do khakhras manufacture?

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3) Discuss briefly the methods of drying.

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4) What is LSU drier?

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REFERENCES BOOK

Handbook on Manufacture of Indian Kitchen Spices (Masala Powder) with Formulations, Processes and Machinery Details (4th Revised Edition)

UNIT-III PRESERVATION BY USING SUGAR

Structure

3.0 INTRODUCTION

The use of sugar syrup is one of the earliest techniques for reducing oxidation. It was used for this purpose for a very long time before the causes of the reactions were identified, and it is still widely used today.

By coating the fruit and shielding it from ambient oxygen, sugar syrup reduces oxidation. Additionally, sugar syrup lends a sweet flavour to fruits that might otherwise be acidic while providing some protection against the loss of volatile fruit esters.

3.1 OBJECTIVES

After reading this unit you should be able to:

- To study sugar and salt preservation
- To know the role of pectin during jam, jelly and marmalade making
- Study the principle of gel formation
- To know about various food preserve

3.2 ROLE OF PECTIN IN PRESERVED FOODS STAGES IN SUGAR COOKERY SUGAR CONCENTRATES

Fruit contains protopectin, pectin, and pectic acid, which are all pectic compounds. Gel formation is prevented by the protopectin found in underripe fruits. When combined with water, the pectin found in properly ripened fruits forms a solution. Because some of the fruit's pectic compounds are still present in the solid portion, heating the fruit with a tiny amount of water is necessary to extract the pectin. Fruit sugars and acids cause the pectin to gel into a jelly when they are present.

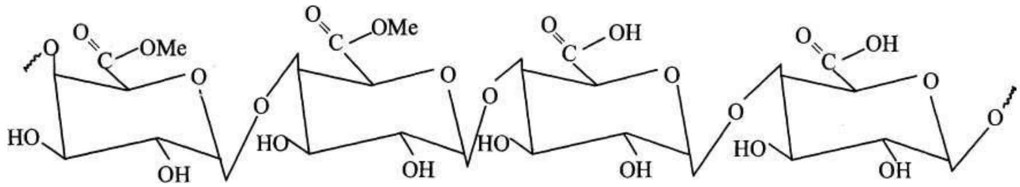


Fig 3.1 pectin chemical structure

Protopectin is the water-insoluble parent pectic chemical found in plants. During fruit ripening, this diminishes and soluble pectin increases. Pectinic acid and pectin are produced via the limited hydrolysis of protopectin. Pectinic acid has a higher than negligible amount of methyl ester groups and forms a colloidal solution. It can combine acid and sugar to make gels. Pectin is a kind of pectinic acid that is water soluble and has different levels of methyl ester neutralisation. When the right circumstances are present, pectin gels with acid and sugar. Galacturonic acid makes up the majority of pectic acid, which is largely free of methyl ester groups.

Citrus peels (or apple pomace) are extracted with diluted acid to yield commercial pectin. Jams and jellies are made using a product in which at least 50% of the carboxyl groups of galacturonic acids have been methylated. The level of methylation should be high (about 60%) for jellies to set quickly. Sugar (65–70%), acid (pH 2.3–3.2), water, and pectin are all necessary for gel formation. The capacity of pectin to remain in a dispersed state is diminished by the acid's rise in unionized carboxyl groups, which lessen the attraction between pectin and water molecules. Sugar competes with water, which further reduces pectin's hydration. When chilled, the unstable dispersion of the less hydrated pectin turns into a gel. By creating cross-linkages between free carboxyl groups and divalent cations like calcium, pectin with a low methoxyl forms concentration gels. In these circumstances, the presence of sugar is not necessary for gel formation.

Only when pectin, acid, sugar, and water are present in specific ratios does a hard jelly develop. The pectin-water equilibrium is disrupted when sugar is introduced to the pectin solution because it works as a drying agent. As a result, the pectin combines and forms a network of insoluble fibres. This mesh-like structure has the capacity to hold large volumes of sugar solution. The structure, continuity, and rigidity of the fibres determine the jelly's strength. The amount of pectin in the system determines the network's continuity, whereas sugar content and acidity determine how firm the network is. The jelly's hardness grows as sugar concentration does. The amount of sugar can be reduced to create a soft jelly. However, acidity affects how quickly things set. When an acid is present, the pectin fibrils toughen and can hold the sugar solution in the interfibrillar gaps. If the acid concentration is high, the fibrils become less elastic and the jelly turns viscous.

3.3 PRINCIPLES OF GEL FORMATION

Pectin does not swell; instead, it precipitates, leading to the production of jelly. The precipitation of pectin only occurs when the balance between the pectin, acid, sugar, and water is exact. The concentration of pectin in solution, the makeup of pectin, the pH of the pectin solution, and the concentration of sugar in solution all affect how quickly precipitation occurs.

Fibrilar theory: According to Cruess, when sugar is added to a pectin solution, the pectin water equilibrium is upset, and the network of fibrils formed by the pectin conglomerates holds the sugar solution in the interfibrillar spaces. The rigidity, continuity, and strength of the fibrils determine the jelly's strength. The more pectin present, the more fibrils develop, and the more extensive and denser the network will be. Acidity and sugar content affect how solid a network is. A reduced amount of sugar can be made up for by using more pectin, as increasing the amount of sugar reduces the amount of water that needs to be supported by pectin fibres. When there is acid present, the pectin's fibrils become tough and may hold sugar. Due to the hydroxylation of pectin with a higher concentration of acid, fibrils become less elastic and the jelly becomes viscous. A weak fibril that is unable to maintain the sugar solution forms when acid is present in lesser amounts. More pectin can be added to make up for it. The degree of pectin breakdown ultimately determines the maximum amount of acid that can be added to the pectin solution without producing any unfavorable effects.

Spencer's theory: Negatively charged pectin particles are present. At a pH of 7, a pectin solution is the most stable. The stability of the pectin solution thus diminishes with an increase in acidity or alkanity. Acid helps sugar serve as a precipitating agent during the creation of jelly. According to their potential to improve or decrease the stability, some salts aid in the precipitation of pectin while others impede it. Therefore, the less sugar is needed, the more acid is present.

Olsen's theory: The following can be anticipated if pectin is thought of as a negatively charged hydrophilic colloid.

- Sugar works as a dewatering agent, upsetting the balance between pectin and water.
- Sugar does not immediately dehydrate the pectin micelles; rather, it needs time to reach equilibrium.
- Pectin precipitates and forms a network of insoluble fibres if the negative charge on it is reduced with the help of an increase in the concentration of hydrogen ions (H+), provided that the concentration of sugar is high enough.
- In direct proportion to the concentration of H+, the rate of pectin hydration and precipitation rises with the addition of acid up to an optimal pH of about 2.0.
- The jelly strength increases to its maximum as the system reaches equilibrium.
- The effects of salt and other components on the system's final jelly strength may be due to changes in the rate of gelation, changes in the final jelly structure, or a combination of both.

Hinton's theory: It is predicated on the idea that pectin are intricate compositions of different factors. It claims that pectin gelations are a type of coagulation in which the coagulated particles create an ongoing network. Only non-ionized pectin, not ionized pectin, contributes to the formation of jelly. Therefore, in order for a mixture to produce jelly, the concentration of non-ionized pectin must surpass a specific saturation limit, which varies depending on the amount of total solids present.

Strength of Pectin Jellies

- *Pectin Content*: Pectin content directly correlates with jelly strength.
- *Acidity*: The pH will be lower and the jelly's strength will increase as acidity increases.
- *Salt content*: Jelly strength is influenced by salt content, gelation temperature, and the amount of time that passes between adding sugar and evenly pouring into containers.
- *Sugar content*: the jelly's potency increases with its sugar concentration
- *Temperature of gelation*: When sugar and pectin are heated to between 21 and 100 °C, more jelly strength is obtained.

Hands on Experience:

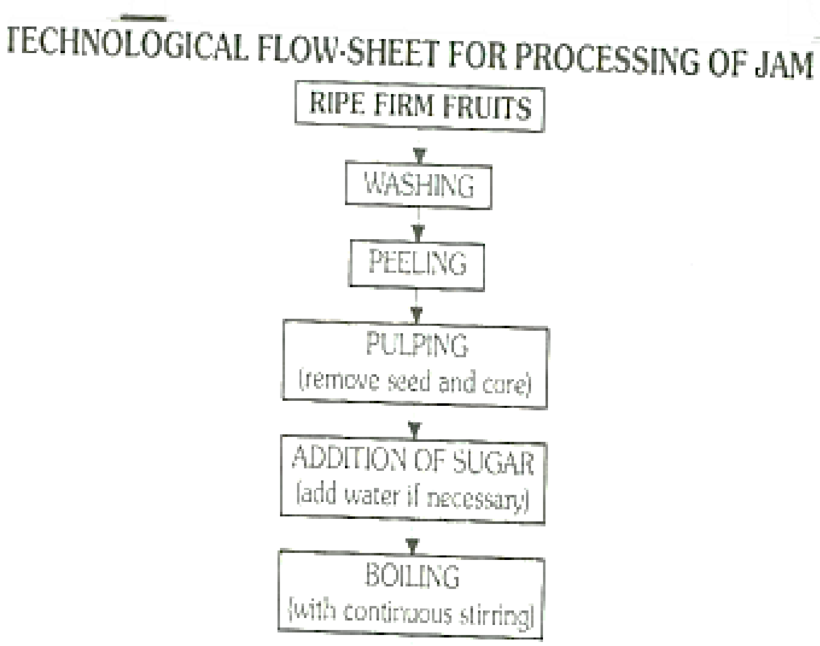
A significant group of preserved fruits include jams, jellies, and marmalades, and methods for making them have been around for a while. Despite more advanced techniques like canning and freezing, this approach is still widely used to preserve fruit since it is convenient and affordable. The technique is based on the pectin found in fruit, when cooked in the presence of the right amount of sugar and acid, forming a gel.

The gel in a **jam** holds the fruit tissues in place. The transparent fruit juice is turned to a gel in a **jelly**. Fruit peels or slices are suspended in a fruit jelly called **marmalade**. **Conserve** is a type of jam prepared from a combination of fruits, almonds, and raisins; **fruit butters** are made from fruit pulp. A **preserve** is made of entire fruit or large pieces of it that have been simmered in a thick syrup until they are soft but still have some structure to them.

3.4 PREPARATION OF JAM, JELLY, AND MARMALADE

Jam

Making jam is a popular practice being done by homes all around the world on a small scale to preserve fruit. The production procedures employed in factories are substantially the same as those used in homes, despite the fact that they now include rigorous quality control techniques to ensure a uniform output. Manufacturing jam in factories is now a highly sophisticated process. A cane or beetroot sugar solution is boiled with fresh or already cooked fruit until enough water has been removed to make a mixture that will gel when cooled and has 32–34% water. When the pH of the fruit is between 3.2 and 3.4 and there is a lot of sugar present in the fruit, the presence of the pectin is required for gel formation. All of the microorganisms in jam are eliminated during the boiling process; therefore, if the jam is put hot into clean containers that are subsequently sealed, and the containers are turned over so that the hot jam contacts the lid surface, microorganism spoiling won't happen during storage. Jam is created by cooking fruit pulp with enough sugar until it is sufficiently thick and hard to hold the fruit tissues in place. Jams are made with apples, pears, sapota (chiku), apricots, loquats, peaches, papayas, karondas, carrots, plums, strawberries, raspberries, tomatoes, grapes, and muskmelon.



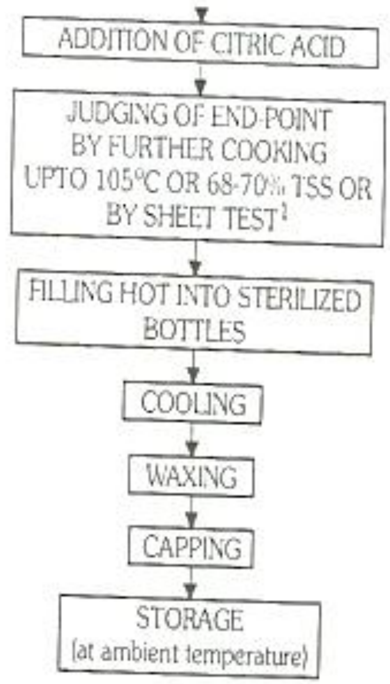
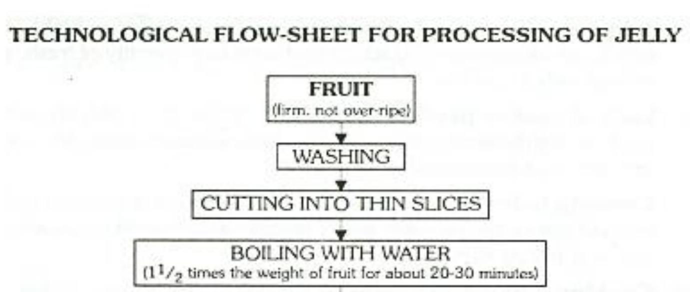


Fig 3.2 processing of jam

Jelly

Jelly is typically made using a mix of slightly overripe and underripe fruits. Since jellies are made from aqueous fruit extracts, peeling fruit is often not required before producing them. Fruits are washed in water. Only a small amount of water should be added to the fruit in order to quickly extract the pectin. Of course, how much water is added will depend on the sort of fruit utilised. Really juicy fruits don't have any water added to them. The pectin extract is filtered by passing it through folded cheese cloth or a bag made of linen. The component that is most important for creating jelly is pectin. If the fruit's pectin level is low, commercial pectin should be applied. Similar to this, it is necessary to add fruits with a high acid content or an acid if the fruit's acid content is low, like citric, tartaric, or malic acid. The mixture is then heated until it reaches the jelly stage by bringing it to a boil. It is then put into glass jars or cans, much like jam.

A good jelly should be translucent, well-set but not overly rigid, and retain the flavour of the fruit it was made from. When taken from the molds, it should maintain its shape and have a pleasing colouring. It should maintain its shape after being cut and have a smooth surface. It need to be soft enough to tremble but not flow.



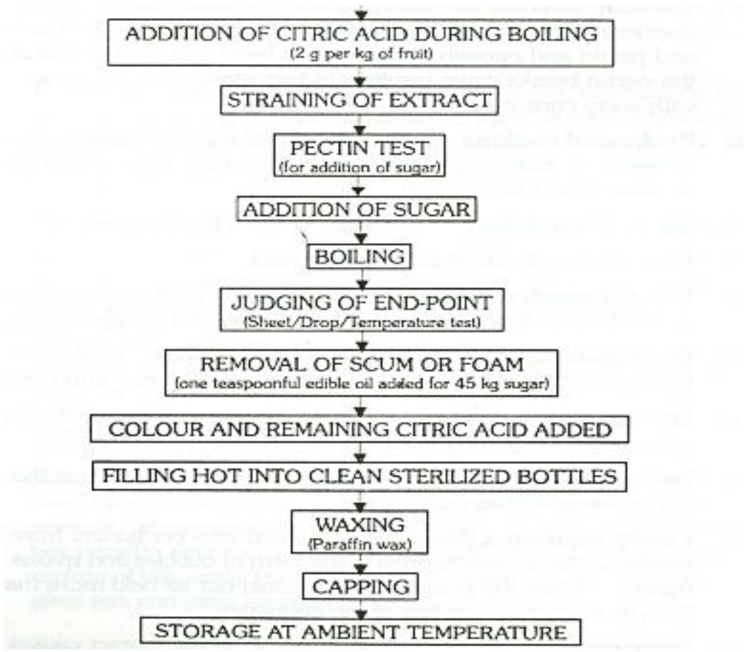


Fig 3.3 Processing of jelly

Marmalades

The product created from citrus fruits, such as oranges, grapefruit, and lemons, in which the shredded peel is included as the suspending material, is known as marmalade. The same processes used to prepare jelly are also employed to make marmalade. The marmalade's pectin and acid level should be a little bit more than what is needed to make jellies. Citrus fruits' outer skin is removed from the actual fruit. To extract pectin, the peeled fruit is cooked in water that is 2-3 times its weight for 45–60 minutes after being sliced into slices or crushed. In certain circumstances, the fruit's aqueous solution is strained (to make jelly marmalade) or run through a coarse sieve to remove gritty debris (to make jam marmalade). Shredded peels that have been cooked in water for 10–15 minutes are added to the fruit extract. After adding the proper amount of sugar, the liquid is cooked until it reaches the jellying stage. When the marmalade is finished, it is packaged similarly to how jams and jellies are.

Marmalades are classified into (i) jelly marmalade, and (ii) jam marmalade.

(1) Jelly marmalade: The following mixtures produce jelly marmalade of high quality: (i) A 2:1 weight ratio of sweet oranges (Malta) and khatta or sour oranges (Citrus aurantium). Peel from a malta orange is used in shreds. (ii) A 2:1 weight ratio of mandarin oranges to khatta. peel from a Malta orange is used in shreds. (iii) Galgal (Citrus iimonia) and sweet orange (Malta) in a weight-to-volume ratio of 2:1. Peel from a Malta orange is used in shreds.

(2) Jam marmalade: Practically the same preparation process as for jelly marmalade. In this instance, the entire pulp is used rather than clarifying the fruit pectin extract. According to the weight of the fruit, sugar is often added in a ratio of 1: 1. TSS concentration in the pulp-sugar mixture is heated until it reaches 65%.

3.5 SAUCE AND SQUASH

Sauce and ketchup are not fundamentally different from one another. However, compared to ketchups (minimum 28%), sauces are typically thinner and have a higher percentage of total solids (minimum

30%). Sauces can be made from tomato, apple, papaya, walnut, soybean,mushroom, etc. There are two types of sauces: (i) thin sauces with low viscosity made primarily of vinegar extract and flavorings such as herbs and spices, and (ii) thick sauces with high viscosities.

Fruit
(firm, not over-ripe)
↓
Washing
↓
Cutting into thin slices
↓
Boiling with water
(1 ½ times the weight of fruit for about 20-30 minutes)
↓
Addition of citric acid during boiling
(2 g per kg of fruit)
↓
Straining of extract
↓
Pectin test
(For addition of sugar)
↓
Addition of sugar
↓
Boiling
↓
Judging of end-point
(sheet/drop/temperature test)
↓
Removal of scum or foam
(one teaspoonful edible oil added for 45 kg sugar)
↓
Colour and remaining citric acid added
↓
Filling hot into clean sterilized bottles
↓
Waxing
(paraffin wax)
↓
Capping
↓
Storage at ambient temperature

Fig. 3.4 Processing of Marmalade

By macerating spices, herbs, fruits, and vegetables in cold vinegar or by boiling them in vinegar, high-quality sauces can be made. The standard commercial procedure is to prepare cold or hot vinegar extracts of each type of spice and fruit separately, blend these extracts appropriately to create sauces, and then allow these sauces to mature. To avoid solid particles settling to the bottom of the sauce, thickening agents are often used. In India, apple pulp is frequently used for this purpose, but potato, maize, arrowroot (cassava), and sago starches are also employed. Fruit tissues should not separate out in the bottle when a fruit sauce is heated to the point where it may be freely dispensed. The sauce should be a vibrant color. On cooling, sauces typically become slightly thicker. Hot ketchup is poured into bottles with a funnel, leaving a 2 cm headspace at the top, and the bottles are immediately corked or sealed. The bottles' necks are sealed airtight by being dipped in paraffin wax when they are cold. Since there is always a risk of fermentation, especially in tomato- and mushroom-based sauces, it is advised to pasteurize sauces after bottling. Even though other sauces are more acidic and less likely to ferment, they still need to be pasteurized for 30 minutes in a pot of boiling water.

The ingredients for tomato sauce/ketchup include strained tomato juice or pulp, spices, salt, sugar, and 1.25-1.50% acid. It can be made with or without onion and garlic, and it must have at least 12% tomato solids and 25% total solids. The general recipe for ketchup is as given below

Ingredient	Quantity
Tomato juice	1 litre
Onion (chopped)	35-40 g
Garlic (Chopped)	5-10 g
Red chillies powder	2-3 g
Spices (Cloves, cardamom, black pepper, cinnamon)	4 g (each)
Glacial acetic acid	2-3 ml
Sugar	20-30g
Salt	10 g
Benzoic acid	750 ppm

Recipe for ketchup

Squash

Squashes are commercially manufactured from various fruits such as mango, orange and pineapple, lemon, lime, bael, guava, litchi, pear, apricot, pummelo, musk melon, papaya, etc., with addition of potassium metabisulphite (KMS) as preservative, or from jamun, passion-fruit, peach, phalsa, plum, mulberry, raspberry, strawberry, grapefruit, etc., with sodium benzoate as preservative (Table 3.1). Squashes, are sometimes fortified with vitamins to enhance their nutritive value, to improve taste, texture or colour and to substitute nutrients lost in processing.

Table 3.1 Represents the concentration of sugar, water, citric acid and preservative for processing of squash from different fruit

S. No.	Fruit	Ingredient for one litre pulp/juice			
		Sugar (kg)	Water (litre)	Citric acid (g)	Preservative (g)
1	Orange*	1.75	1.0	20	2.5 KMS
2	Mango	1.75	1.0	20	2.5 KMS
3	lime, Lemon	2.0	1.0	-	2.5 KMS
4	Bael	1.80	1.0	25	2.5 KMS
5	litchi	1.80	1.0	25	2.25 KMS
6	Pineapple	1.75	1.0	20	1.9 KMS
7	Guava	1.80	1.0	20	2.0 KMS
8	Papaya	1.80	1.0	25	2.5 KMS
9	Karonda	1.80	1.0	5	4.0SB
10	Phalsa	1.80	1.0	5	4.0SB
11	Jamun	1.80	1.0	15	3.0SB
12	Plum	1.90	1.0	10	4.0SB
13	Water melon	0.50	0.25	10	1.5 SB
KMS= Potassium metabisulphite SB= Sodium					

3.6 PRESERVES, CANDIED, GLAZED, CRYSTALLIZED FRUITS, TOFFEE

Preserves

A ripe fruit or vegetable, or one of its components, that has been highly sweetened till it is tender and translucent, is referred to as a preserve. Fruits like apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, etc. can be used to make preserves. You may prepare these at home using 1 kg of fruit, 1 liter of water, and 1 kg of sugar. To prevent the syrup from crystallizing, a small amount of acid (citric or tartaric) is added during preparation.

Candy

Crystalline and non-crystalline (amorphous) sweets are made from boiled sugar solution. The nature of the finished product depends on the boiling sugar solution temperature, the components employed, and the handling procedures for the supercooled sugar solution. Crystalline sweets can be cut with a knife and are easily chewed. Fondant and fudge are the main crystalline candies. When making crystalline candy with a smooth and velvety texture, much attention must be taken. In contrast, amorphous candies (such as toffee and brittles) have a heterogeneous structure and break into pieces rather than being cut with a knife into the appropriate forms. However, caramels—the softest of the amorphous candies—can be cut.

Mature fruits

Washing

Preparing Fruits for Sugar treatment

Adding fruits in sugar in layer

Removal of fruits

Increasing the consistency of syrup

soaking fruits

Repeating the process and increasing the strength of the syrup
(by 5% to 70% TSS for preserve or 75% TSS for Candy)

Steeping in 70% TSS for a week

Preserve

Draining syrup

Repeating the process and increasing the strength of the syrup
(by 5% to 70% TSS for preserve or 75% TSS for Candy)

Steeping in 70% TSS for a week

Preserve

Draining syrup

Filling in jar

Fruit covering with freshly prepared syrup of 68% TSS

Sealing

Storage

Table 3.2 Temperature test for syrups and cadies

Product	Temp 0°C	Test	Description of test
Syrup	110-112	Thread	When syrup is dropped from a spoon, syrup spins a 5 cm thread
Barfi, Fondant, Fudge	112-115	Softball	Forms a soft ball when syrup is dropped into cold water; flattens on removal from water
Caramel	118-120	Firm ball	Forms a firm ball when syrup is dropped into cold water; does not flatten on removal from water
Divinity, *Ladu (Laddoo)*, Marshmallow	120-130	Hard ball	Forms a ball hard enough t Md its shape when syrup is dropped into cold water
Butterscotch, Toffee	132-143	Soft crack	Forms threads which are hard but not brittle when syrup is dropped into cold water
Brittle, Glace	150-154	Hard crack	Forms thread which are brittle when syrup is dropped
Barley Sugar	160	Clear liquid	Sugar melts
Caramel	170	Brown liquid	Sugar melts and browns

Source: *Indian Journal of Home Science*. Vol.7, p. 152.

Preserve

Glazed, fruits and vegetables with glaze

Giving candied fruits and vegetables a thin, transparent sugar coating to give them a shining appearance is known as glazing. The guidelines supplied by Cruess for glazing fruits are as follows: Cane sugar and water are combined in a steam pan and heated to 113–114°C. As the scum rises, it is scraped off. The syrup is then cooled to 93°C and scraped over the pan's surface with a wooden spoon to make granular sugar. Before being put on trays and kept in a warm, dry atmosphere, dried candied fruits are individually pushed through this granular section of the sugar solution using a fork. They can also be dried in a dryer for a few hours at 49°C. They are set inside airtight jars.

Crystallized Fruits Fudge and fondant are crystalline sweets. The amount of sugar used must be completely dissolved by adding enough water as the first stage in making sugar-boiled sweets. A smooth-textured, soft-yet-firm result is desired in crystalline or cream candies. This is made feasible by adding components to the sugar solution that promote the growth of tiny crystals. In order to make fondant, substances including acid (cream of tartar), inverted sugar, and glucose or corn syrup are added. The solution of the candy combination is then concentrated by boiling it until it reaches the proper doneness. Slow heating causes excessive acid hydrolysis and could result in an overly pliable product. The creation of the sugar molds utilized in this nation for special occasions likewise follows this approach. The temperature of the boiling solution is used to gauge the candy mixture's readiness. The ideal temperature for fondant is between 113°C and 114°C. Dropping a little amount of boiling syrup into ice-cold water, letting it cool, and then judging the consistency of the syrup is another way to determine when candy is done. It is the softball form in the case of fondant. Table 26.3 lists the consistency of syrup at various temperatures.

Toffee

Amorphous candies are a little simpler to produce than crystalline ones. Sugar crystallisation can be avoided by heating the solution to a high temperature so that the final product hardens quickly before crystals have a chance to form, by adding a lot of compounds that interfere with crystal formation, or by doing both at once. Different confections require different temperatures to be created. The final syrup temperature for caramels is between 118° and 120°C. When milk is one of the ingredients, caramelization of sugar as well as interactions between the amino groups of milk proteins and reducing sugars cause a brown colour to appear during cooking. Corn syrup, lipids and concentrated milk products are used as components while making caramels, Brittles are simply produced by melting and caramelizing sugar. Simple sucrose syrup is the base for toffee, which is then flavored with cream of tartar, vinegar, or lemon juice. When the solution has cooled enough, flavorings are added. Gelatin is used to make spongy candy like marshmallow and gum drops.

3.7 EVALUATION OF PH, ACIDITY AND PECTIN QUALITY

Measurement of grades of pectin

Initially pectin was graded as per SAG value but now a days it is being estimated as breaking strength and as internal strength as being measured by pektinometer and Stevens- LFRA Texture Analyzer respectively.

Pectin and gel formation

When the proportion of soluble solids is less than 25%, pectin is easily soluble in water. Pectin will dehydrate as the amount of sugar or total solids [TS%] grows through processing and the free moisture is taken away. Because pectin molecules in solution are negatively charged, they will oppose one another when the precipitated macromolecule forms a lattice across the gel. Reduced repulsion will result from reducing pH [raising hydrogen ion concentration], and gel.

Pectin content assessment:

One of the two approaches listed below is typically used to assess the pectin content of the strained extract.

(i) Alcohol test: The steps for this technique, which involves precipitating pectin with alcohol, are listed below:

Three teaspoonfuls of methylated spirit are carefully poured down the side of a beaker that has been filled with one teaspoon of strained extract, cooled, and turned for mixing. The beaker is then left to stand for a few minutes.

(a) A single, clear lump or clot will form in pectin-rich extracts. The extract must be combined with an equal amount of sugar to make jelly.

(b) The clot will be less rigid and fractured if the extract contains a considerable/moderate amount of pectin.

(c) If the pectin content of the extract is low, many tiny granular clots will be present. Add half as much sugar has been added.

(ii) The jelmeter test: The thumb and forefinger of the left hand are used to hold the jelmeter. With the little finger, the jelmeter tube's bottom is sealed. With a spoon held in the right hand and the strained extract being poured into the jelmeter until it is completely full. The little finger is taken off the bottomend of the jelmeter while it is still being held, and the extract is allowed to drip or flow for exactly one minute before being reinstalled. The extract level in the jelmeter is noted in the reading.

Acid

The amount of acid and pectin in the fruit determines how jelly-like the extract will be. Tartaric acid performs best among the three acids found in fruits—citric, malic, and tartaric. The finished jelly should have at least 0.5% (ideally 0.75%) of total acids, but no more than 1%, as too much acid may result in syneresis.

Extract's pH: Until the pH is optimal, jelly strength increases as pH rises. The jelly's strength is decreased with more acid addition. For a jelly with 1% pectin, the ideal pH is roughly 3.0, 3.2, and 3.4 for 60%, 65, and 70% TSS, respectively.

Visit to Fruits and Vegetable processing industry.

3.8 LET US SUM UP

In this unit, we have learnt about what is fruit preservation. fruits have high water activity and hence are more prone to spoilage. They can be preserved through the sugar concentration process. Fruit preservation is mainly done by using high concentrations of sugar or salt leading to the osmosis process which results in reducing the water activity of the fruit. In this unit, some of the fruit preserves and their manufacturing process are discussed.

3.9 CHECK YOUR PROGRESS

Note: Use the spaces given below for your answers.

1) What is the principle of gel formation?

……
……
………………………………………………………………………..

2) What are the processing steps involved in jam manufacturing?

……
……
…………………………………………………………………………

3) Discuss briefly the pectin test during jelly-making.

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………………………………………………………………………….

4) Enlist different types of fruit preserves.

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………………………………………………………………………….

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- William C Frazier 2014 Food Microbiology Fifth Edition Published by McGraw Hill Education (India) Private Limited
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BLOCK-II

PRESERVATION BY USING SUGAR, CHEMICALS, SALTS, AND ADVANCED PRESERVATION

UNIT IV PRESERVATION BY USING CHEMICALS AND SALTS AND FERMENTATION: Preparation and Preservation of Fruit Juices, RTS Pickling – Principles Involved and Types of Pickles Chemical Preservatives – Definition, Role of Preservation Permitted Preservatives, FSSAI guidelines Foods fermented by Yeasts Foods fermented by Bacteria Common Fermented Foods, Wine and Cheese Making Hands on experience: Pickle making Visit to Commercial Pickle Manufacturing Food Industry and Wine industry

UNIT V PRESERVATION BY ADVANCED PRESERVATION TECHNOLOGY: Meaning and needs of freezing foods Types of Freezing and managing freezers Guidelines for types of frozen foods-Fruits, Vegetables, fish, meat and poultry Smoking foods Pasteurization and Sterilization Food Irradiation Vacuum Packing Canning and Bottling Food Packaging Materials for preserved food products

Hands on experience: Blanching of fruits & Vegetables Visit to Food Industries

UNIT-IV PRESERVATION BY USING CHEMICALS AND SALTS AND FERMENTATION

Structure

4.0 INTRODUCTION

Osmotic dehydration, which is achieved by soaking the solid food, whole or in part, in aqueous solutions of sugars or salts that have a high osmotic pressure, is a useful technique for concentrating fruit and vegetables. A considerable water flow from the meal into the solution and a solute transfer from the solution into the food both happen concurrently as a result, creating at least two significant counter-current flows.

The goal of all currently known food preservation techniques, including application of heat, cold, removal of water, and other techniques, is to either reduce the quantity of microorganisms in food or to prevent them from proliferating further. Contrarily, the proliferation of microorganisms and their metabolic processes are promoted during the fermentation process of food preservation. However, only a few types of organisms are promoted to proliferate and grow because their metabolic byproducts aid in food preservation. The term "fermentation" refers to the anaerobic breakdown of carbohydrate material by microorganisms (or enzymes). The breakdown of carbohydrates and carbohydrate-like substances occurs both anaerobically and aerobically, and is referred to as "fermentation" in common usage. Therefore, the processes of Streptococcus lactis converting lactose to lactic acid under anaerobic conditions and Acetobacter aceti converting ethyl alcohol to acetic acid under aerobic conditions are both referred to as fermentation.

Since ancient times, natural fermentations have been essential for the preservation of food. Fruit juices that were exposed to the air naturally fermented and took on an alcoholic flavour. Standing milk had a mild acidic flavour. Therefore, these modifications were used to preserve foods that would otherwise spoil quickly. At the same time, some found the altered flavour and texture of fermented meals to be appealing. These are the main justifications for fermentation's continuous usage in food processing and preservation. Cheese, curd, butter, all alcoholic beverages, pickles, sauerkraut, vinegar, bread, idli, soy sauce, coffee, tea, and chocolate are just a few of the numerous items that can be made through fermentation.

4.1 OBJECTIVES

After reading this unit you should be able to:

- know about the methods of preserving fruit juice and RTS;
- learn various methods of pickling as a preservation method;
- know about types of fermented food and beverage;
- study FSSAI guidelines for fermented foods

4.2 PREPARATION AND PRESERVATION OF FRUIT JUICES, RTS

Fruit Juices

Juices come in two varieties:

(a) **Natural juice:** it is also known as pure juice, is the juice that has been extracted from ripe fruits and solely includes natural sugars.

(b) **Sweetened juice:** This liquid product has a minimum juice content of 85% and maximum total soluble solids content of 10%. Pure fruit juices, including apple juice and orange juice, are produced for sale in a number of nations. While other juices are typically canned, apple juice is typically bottled. The following are the methods for making different fruit juices:

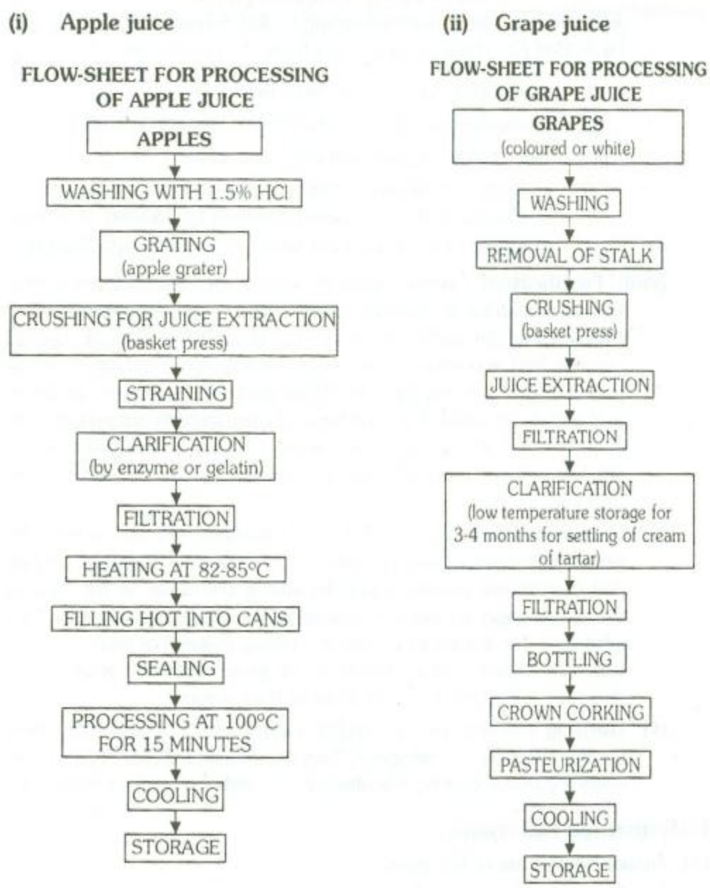

Fig 4.1 processing of apple and grape juice

Pasteurization is used to preserve fruit juices, RTS, and nectars, but chemical preservatives are occasionally used. The only way to preserve squashes, crushes, and cordials is by adding chemicals. Syrup has a high enough concentration of sugar to keep it from spoiling. Fruit juice concentrates are preserved through the use of heat, freezing, or chemical additions.

RTS (Ready-to-Serve)

In addition to roughly 0.3% acid, this type of fruit beverage comprises at least 10% fruit juice and 10% total soluble solids. It is called ready-to-serve (RTS) since it hasn't been diluted before consumption. Knowing how to remove the pulp and juice from different fruits used to make RTS, nectar, squash, syrup, etc. is important before beginning the beverage production process. Some fruits' extraction methods have already been mentioned, while others are as follows. Before adding the necessary amounts of sugar and citric acid dissolved in water for TSS and acidity adjustment, the total soluble solids (TSS) in the pulp/juice and its acidity are first determined for the preparation of the beverages.

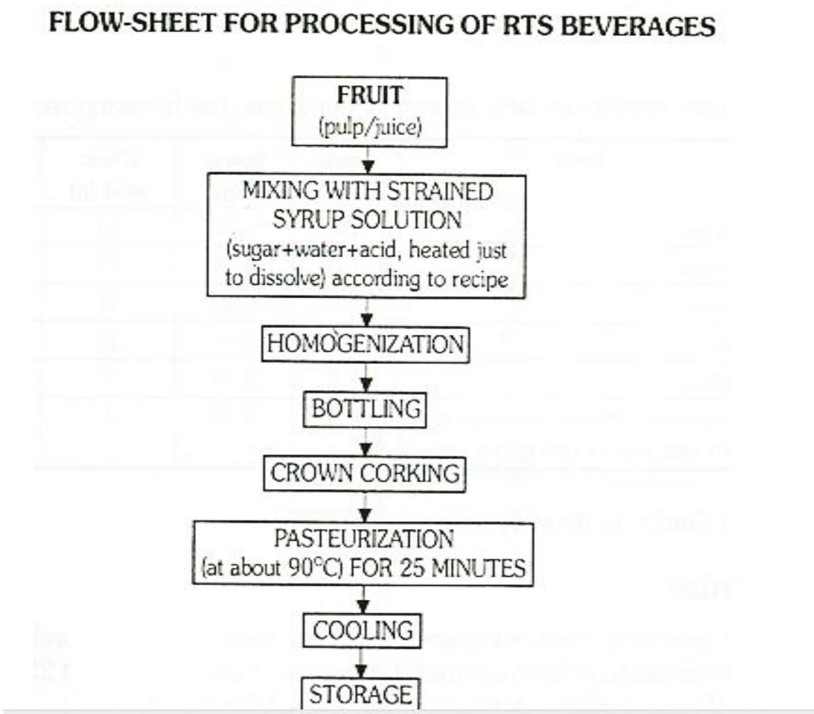

Fig 4.2 processing of RTS

4.3 PICKLING – PRINCIPLES INVOLVED AND TYPES OF PICKLES

Pickles

Pickling is the process of preserving food in vinegar or table salt. One of the oldest techniques for preserving fruits and vegetables. Pickles make a meal more palatable and make for tasty appetizers. They aid in digestion by promoting the flow of gastric juice. The Indian market offers a variety of pickles. Cauliflower, onion, turnip, and lime pickles come in second place, after mango pickles. These are frequently produced both commercially and at home, and they are also exported. Vegetables are typically pre-served in salt, and fruits are typically kept in sweetened and flavoured vinegar.

Principle of pickling: Lactic acid-forming bacteria, which are often abundant on the surface of fresh vegetables and fruits, ferment foods to produce pickling. These bacteria may thrive in an acidic environment and in the presence of an 8–10% salt solution, whereas the majority of harmful organisms have their growth suppressed. In the early stages of preparing pickles, the temperature must be kept as close to 30°C as possible since lactic acid bacteria are most active at this temperature. When vegetables are submerged in brine, it seeps into their tissues and soluble substances disperse through osmosis into the brine. Minerals and fermentable carbohydrates are included in the soluble material. Lactic acid bacteria feed on the sugars, converting them into lactic and other acids as a result. The resulting acidic brine reacts with the vegetable tissues to give pickles their distinctive flavour and scent. In the dry salting method, a vessel covered with a cloth and a wooden board and let to stand for about 24 hours is filled with multiple alternating layers of vegetables and salt (20- 30 g of dry salt per kg of vegetables). Osmosis causes enough juice from the veggies to escape during this time, forming brine. Vegetables are covered with brine (steeping in a concentrated salt solution is known as brining) if they don't have enough juice (like cucumber, for example) to dissolve the salt that has been added.

Pickles are currently made and preserve with salt, vinegar, oil, or a combination of salt, vinegar, oil, and spices. The following methods are covered:

(1) Salt preservation

Salt enhances flavour, increases vegetable tissue hardness, and inhibits fermentation. A 15% salt concentration or more prevents microbiological deterioration. This method of preservation is typically only utilised for vegetables that have a very low sugar content because this limits the amount of lactic acid that can be produced during fermentation to serve as a preservative. However, salt is also used to preserve some fruits, including lime, mango, and others. The following is a description of how various pickles are made:

(i) Lime pickle: 1 kg of limes, 200 g of salt, 15 g of red chilli powder, huge cinnamon, cumin, and cardamom pods, and powdered black pepper.

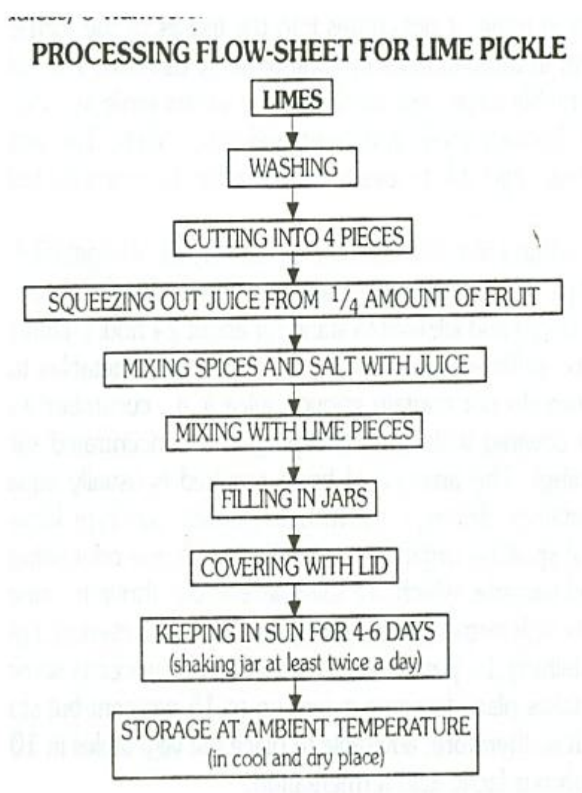

Fig 4.3 processing of lime pickle

(2) Vinegar preservation

A variety of fruits and vegetables are preserved in vinegar, which should have a final acetic acid concentration in the finished pickle that is no less than 2%. The vegetables or fruits are typically placed in strong vinegar of about 10% strength for several days before pickling, which helps to expel the gases present in intercellular spaces of vegetable tissue and prevents vinegar below this strength from being diluted by the water released from the tissues. The most significant pickles eaten abroad are vinegar pickles. In vinegar, items such as mangoes, garlic, chilies, etc. are preserved. ex(i) Papaya pickle: 1 kilograms of peeled papaya chunks, 100 g of salt, 10 g of red chilli powder, 1 cup of cumin, powdered black pepper 10 g, vinegar 750 ml.

(3) Oil-based preservation

The edible oil needs to cover the fruits or vegetables entirely. The most significant oil pickles are turnip, lime, mango, and cauliflower. approaches to below is how some oil pickles are made:

Pickled mango: Mango pieces 1 kg, salt 150 g, fenugreek (powdered) 25 g, turmeric (powdered) 15 g, nigella seeds 15 g, red chilli powder 10 g, clove (headless) 8 numbers, black pepper, cumin, cardamom (large), aniseed (powdered) each 15 g, asafoetida 2 g, mustard oil 350 ml Gust adequate to cover pieces).

(4) Preserving with a salt, oil, spice, and vinegar mixture

Cauliflower pickle ingredients include 1 kg of chopped cauliflower, 150 g of salt, 25 g of chopped ginger, 50 g of chopped onion, 10 g of chopped garlic, 15 g each of powdered cardamom, cumin, and aniseed, 6 g each of headless cloves, and 50 g each of ground mustard and tamarind pulp.

4.4 CHEMICAL PRESERVATIVES – DEFINITION, ROLE OF PRESERVATION PERMITTED PRESERVATIVES,

To inhibit microbial degradation of food products, chemical preservatives are utilised that solely contain microbial antagonists as opposed to salt, sugar, acetic acid, oils, or alcohols. Preservatives interfere with the mechanisms of cell division, cell membrane permeability, and enzyme activity, which results in their inhibitory actions.

Pasteurized squashes, cordials, and crushes have a cooked flavour. After the container is opened, they quickly begin to ferment and spoil, especially in a tropical climate. To stop this, chemical preservatives are necessary. Chemically preserved squashes and crushes can be kept for a while even after the seal on the bottle has been broken. Chemical use must be carefully regulated, nevertheless, as their indiscriminate use is likely to be detrimental. The preservative utilized shouldn't be unhealthy or irritant to the skin. It should be straightforward to calculate and identify.

The British Food and Drug Act of 1928 defines a "preservative" as any substance that has the ability to prevent food from fermenting, becoming acidic, or otherwise decomposing. Common salt (sodium chloride), saltpetre (sodium or potassium nitrate), sugar, acetic acid or vinegar, alcohol or potable spirits, spices, essential oils, or any other substance added to the food during the smoking process are not considered to be "preservatives." Sulphur dioxide (including sulphites) and benzoic acid (including benzoates) are the two significant chemical preservatives that are approved in many nations. According to the Fruit Product Order (F.P.O.) of 1955, these two are also permitted in India. Sulphur dioxide is commonly used all over the world to preserve items like juice, pulp, nectar, squash, crush, and cordial. It effectively prevents the growth of germs and mould, inhibits enzymes, etc. It also functions as a bleaching and antioxidant agent. These characteristics aid in the retention of oxidizable substances such as carotene, ascorbic acid, and others. Additionally, it prevents the product from developing nonenzymatic browning or discoloration after the enzyme has been destroyed. Typically, its salts, such as sulphite, bisulphite, and metabisulphite, are used.

Sodium benzoate, is employed since it is only slightly soluble in water. At room temperature, one part of sodium benzoate dissolves in 1.8 parts of water, but one part of benzoic acid dissolves in just 0.34 parts of water. Therefore, sodium benzoate is almost 1170 times more soluble than benzoic acid. Pure sodium benzoate has neither flavour or aroma. *Bacillus subtilis* cannot survive in a solution of benzoic acid in the presence of carbon dioxide, demonstrating the enhanced antibacterial effect of benzoic acid in the presence of both carbon dioxide and acid. Benzoic acid works better against yeast than it does against mould. Lactic acid and acetic acid fermentation are not stopped. The amount of benzoic acid needed will vary depending on the product's composition, notably how acidic it is. The addition of 0.06 to 0.10 percent of sodium benzoate has been found to be sufficient for juices with a pH of 3.5 to 4.0, which is the range of most fruit juices. A minimum of 0.3% is required for less acidic liquids like grape juice. At pH 5.0, benzoic acid's effect is significantly diminished. Over 0.1% sodium benzoate may result in an unpleasant burning taste. The permissible level in RTS and nectar is 100 ppm, while in squash, crush, and cordial it is 600 ppm, according to the F.P.O. Several substances that were once used as preservatives, including hydrogen peroxide, formaldehyde, halogenated acetic acid, salicylic acid, etc., have now been outlawed in many nations. Tylosin (a macrolide antibiotic that is active against Gram-positive bacteria and mycoplasmas), sorbic acid, and other substances have all been tested recently.

FSSAI guidelines Foods fermented by Yeasts Foods fermented by Bacteria

Up until the date of minimal durability, the starter microorganisms must be present in the product in a viable, active, and plentiful state. The starter culture must contain a total of 107 cfu/g of microorganisms. The labelled microorganisms must not be fewer than 106 cfu/g. These requirements for live microorganisms do not apply if the product is heated after fermentation. The presence of the commonly used starter cultures of lactic acid producing bacteria such as *Lactococcus* spp., earlier known as *Streptococcus* spp., *Lactobacillus* spp. and other such microorganisms used in the preparation of fermented milk (dahi) and related products shall not be considered as probiotics, if the probiotic properties have not been substantiated.

The viable number of organisms in food with added probiotic ingredients shall be≥108 CFU/g:

Provided that a lower viable number may be specified with proven studies on health benefits with those numbers subject to the prior approval of the Food Authority.

4.5 Common Fermented Foods

The phrase "fermented foods" designates a particular class of food items that occasionally show different patterns of carbohydrate breakdown. Most fermented meals are composed of a complex mixture of proteins, lipids, carbohydrates, and other substances that are being changed simultaneously or in some sequence by a variety of bacteria and enzymes. Therefore, additional terminology is needed to distinguish between the various important types of change. Reactions involving carbohydrates and compounds that resemble carbohydrates are referred to as "fermentative" reactions (actual fermentations). Proteolytic or putrefactive transformations occur in proteinaceous materials. Lipolytic refers to the breakdown of fatty compounds. When complex foods are "fermented" naturally, they always go through varying degrees of each of these types of changes. It will either be fermentative, proteolytic, or lipolytic end products that predominate, depending on the nature of the meal, the types of bacteria present, and environmental conditions effecting their development and metabolic inclinations. Acetic, lactic, and alcoholic fermentation are the three main types utilized to preserve fruits and vegetables.

Additionally helpful in preserving the healthy microbiota composition of celiac disease, fermented food products can support physiological homeostasis and play a critical role in disease prevention. We can also refer to fermented food products as naturally energizing edibles. According on which food product has been fermented, there are numerous sorts of fermented goods still available on the market. They fit into the following categories. (i) cereal-based (with/without pulses) fermented foods, (ii) cereal/pulse and buttermilk-based fermented food: those made with cereal/pulse and buttermilk, (iii) cereal-based fermented sweets and snacks, (iv) milk-based fermented foods, (v) vegetable, bamboo shoot (BS) and unripe fruits-based fermented foods, (vi) meat based fermented foods and (vii) pulse (legume)-based fermented food

Wine

Wine Different nations' legal systems define wine differently; for instance, in China, wine is regarded as an alcoholic beverage and is referred to as appetite wine. It is referred to as the fermented juice of several fruits in California. However, wine generally refers to the end result of the fermentation of grape juice. The most apt description appears to be "wine is a beverage resulting from the fermentation by yeasts of the grape juice with proper processing and addition." In other words, wine strictly refers to the alcoholic beverage made from grape juice that has undergone fermentation but not distillation. Historically, grapes have been used to make wine for the following reasons: (i) Juice has a tremendous amount of natural sugar. (ii) The berries' organic connection with fermenting yeasts. (iii) A high amount of nitrogenous substances helps fermentation by boosting yeast development. (iv) Juice's high acidity favours yeast growth and guards against the fermentation of other microorganisms. (v) The fermented wine is stable and safe for long-term preservation because of its high alcohol and acid levels. Wines come in countless variations and have so many unique qualities that it is challenging to categorize them. There are two sorts, red and white, based on colour. There are two types of grape wines: dry and sweet. Wines that can't be detected as having any sugar are said to be dry. The sugar concentration in sweet wines is significant enough to taste. These two types of wines have an alcohol percentage that ranges from 7 to 20%. "Light" wines are those that have 7 to 9 percent alcohol by volume, "medium" wines have 9 to 16 percent, and "strong" wines have 16 to 21 percent. CO_2 is present in sparkling wine. They undergo secondary fermentation in tightly sealed containers, usually the bottle itself, to become fizzy. Wines classified as "still" don't have any carbon dioxide in them. Brandy, an additional form of alcohol, is added to fortified wines. Wines that contain more than 12% alcohol are typically fortified with fruit brandy, which is alcohol made by distilling grape wine.

Fig 4.4 Processing of wine

Diverse types of marketable wines are listed below: **Champagne**: it is a foaming wine which contains dissolved carbon dioxide. **Sparkling wine**: it is produced by carbonation by injecting carbon dioxide into the wine. **Liqueur Wine:** it is sweet with a higher content of alcohol. **Sherry**: it is a fortified wine with two distinct styles, the first being dry wine (without any sweet taste) consumed as an appetizer before meals and the other being olorosos sweetened wine taken after meals. • **Port**: it is a type in which wine is stored in a wooden cask or Hintage ports. During maturation the type of barrel used for aging contributes to quality of wine. **Vermouth**: it is a flavored wine in which different varieties of herbs and spices are added. **Brandy:** It is a distilled wine stored mostly in wooden cooperage or casks.

Cheese Making

Cheese is made from around one-third of the milk produced annually in the United States. The production of natural and processed cheeses was 9.7 billion pounds in 1998. Cheese, which was made by adding rennet (an enzyme found in a calf's stomach) to sour milk, which is only possible by exposing milk to microbes, can undoubtedly be considered as one of the first direct products (or by-products) of biotechnology, even though this understanding was not present at the time. All cheeses are made from milk, however the variety of cheeses that are currently on the market is produced using various manufacturing and ageing techniques. Milk from cows, goats, and buffaloes can all be used to make cheese. Making cheese involves coagulating or curdling milk, boiling the curd, stirring it, removing the whey (the liquid portion of the milk), collecting, and pressing the curd, and occasionally ripening it. Whole milk, 2% low-fat milk, 1% low-fat milk, fat-free milk, or a combination of these milks can all be used to make cheese. There are more than 400 different kinds of cheese to choose from. There are various classifications for cheeses, including natural versus processed, unripened versus matured, and soft versus hard. Many cheeses bear the name of the town or region where they were first produced, such as the English cheese known as Cheddar.

Natural cheeses are frequently divided into groups based on their moisture content or level of softness or hardness.

- Casein, a milk protein, is coagulated with acid to produce unripened cheeses.
- For instance, ripened cheeses are produced by coagulating milk proteins with enzymes (rennet) and culture acids. Soft cheeses like cream cheese, cottage cheese, and Neufchatel are examples of this type of cheese. Then, bacteria or mould ripen (age) the cheeses. Cheeses that have been matured by bacteria include Cheddar, Swiss, Colby, brick, and Parmesan.
- Mold Mold-ripened cheeses include ripened cheeses like.

Natural cheeses include:

- **Soft Cheeses:** Brie, Camembert, ricotta, cottage
- **Semi-Soft Cheeses:** Blue, brick, feta, Havarti, Monterey Jack, mozzarella, Meunster, provolone
- **Hard Cheeses:** Cheddar, Colby, Edam, Gouda, Swiss
- **Very Hard Cheese:** Parmesan, Romano
- **Process Cheeses.** These cheeses are made by blending one or more natural cheeses, heating and adding emulsifying salts. Process cheeses contain more moisture than natural cheeses.
- **Pasteurized process cheeses** include American cheese, cheese spreads and cheese foods.
- Cold-pack cheese is a blend of natural cheeses processed without heat.

Hands on experience: Pickle making Visit to Commercial Pickle Manufacturing Food Industry and Wine industry.

4.6 LET US SUM UP

In this unit, we have learnt about what is fermentation. Pickling is also one of the oldest known methods of preservation. Fermented food is easily digestible, having more nutrients with increased bioavailability. In this unit, some of the fermented foods like cheese, wine etc. and their manufacturing process are discussed.

4.7 CHECK YOUR PROGRESS

Note: Use the spaces given below for your answers.

1) What is the principle of pickling?

……..

2) What are the processing steps involved in wine manufacturing?

……

3) Discuss the manufacturing process of cheese.

…….

4) Enlist different types of fermented food with their health benefits.

…….

REFERENCES BOOK

Wood, B.J.R. (Editor) (1985) Microbiology of Fermented Foods, Volumes 1, 371 pp & Volume 2, 292 pp. Elsevier Applied Science Publishers. London and New York. [This two-volume book discusses the microbiology of fermented foods from around the world].

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UNIT-V PRESERVATION BY ADVANCED PRESERVATION TECHNOLOGY

Structure

5.0 INTRODUCTION

Through the ages, modern techniques for food preservation have evolved based on earlier techniques. The 19th century saw the modest beginnings of industrial food processing, but this century has seen enormous advancements. The fundamental goal of all food preservation methods, whether they are used at home or in industrial settings, is to prevent food from spoiling so that it can be utilized later on without risk and in a delectable state. Methods of preservation are intended to prevent the spread of organisms as well as their removal and eradication. The biochemical degradation of tissues and the change of their cell contents should also be halted by food preservation. Heat, cold, drying, fermentation, radiation, and chemicals are used to accomplish this.

Freezing

Many foods can be successfully frozen to extend their shelf life and preserve them for a very long time. The technique, according to Fennema et al. (1973), involves lowering the product's temperature to -18 °C or lower. The physical state of food is changed when energy is removed from it by chilling it below the freezing point. Only chemical changes that affect food quality or cause it to decay, as well as the development of microbes, are slowed by extremely cold temperatures (George, 1993).

5.1 OBJECTIVES

After reading this unit you should be able to:

- know about the methods of low temperature preservation;
- learn various methods of freezing and types of freezers;
- know about types of food irradiation;
- study different types of food preservation such as aseptic canning and bottling, pasteurization, sterilization, etc.

5.2 MEANING AND NEEDS OF FREEZING FOODS

As was already said, ancient humans were aware of the benefits of freezing and cold storage for food preservation. Tribes and countries in temperate and cooler climates preserved their crop by freezing them, thawing them as needed, and eating it. Even short distances to consumption centers were covered by the transportation of frozen meals. The advent of mechanical refrigeration systems has led to a rise in the use of cold storage, processing, and delivery of food. Agriculture practices have also been impacted by refrigeration. Perishable foods can now be transported over great distances from the point of production to the point of consumption, and seasonal foods can now be found all year round.

Storage that keeps food in a frozen state is referred to as frozen storage. Normal requirements for good frozen storage are -18°C or lower. Since fresh foods contain so much water, freezing them takes a lot of energy, which is why the frozen fruit and vegetable industry uses so much of it. The refrigeration burden is lessened when a material is frozen due to its moisture content.

Fruits and vegetables can be partially concentrated before freezing to minimize packing and delivery costs and to increase product quality because there is a significantly lower danger of structural collapse and leaking when the food is thawed.

The final goods are referred to as "dehydro-frozen" products, and the concentration step is frequently finished by conventional air drying, with an additional expense to take into account. Osmotic dehydration may be employed in place of air drying to save energy consumption or enhance product quality, especially for produce that is air-sensitive.

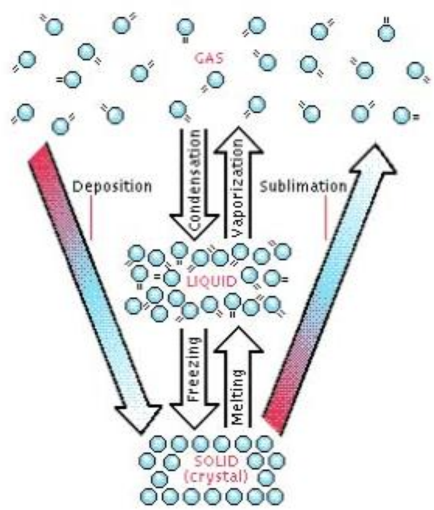

Fig 5.1 Schematic representation of freezing process
Source:https://www.fao.org/3/y5979e/y5979e03.htm

5.3 TYPES OF FREEZING AND MANAGING FREEZERS

Freezing of Foods, the rate of freezing of foods depends on a number of factors, such as the method employed, the temperature, circulation of air or refrigerant, size and shape of package, and kind of food. Sharp freezing usually refers to freezing in air with only natural air circulation or at best with electric fans. The temperature is usually −23.3 C or lower but may vary from −15 to −29 C, and freezing may take from 3 to 72 hr. This sometimes is termed **slow freezing** to contrast it to quick freezing, in which the food is frozen in a relatively short time. **Quick freezing** is variously defined but in general implies a freezing time of 30 min or less and usually the freezing of small packages or units of food.

Quick freezing is accomplished by one of three general methods**:**

(1) Direct immersion of the food or the packaged food in a refrigerant, as in the freezing of fish in brine or of berries in special sirups.

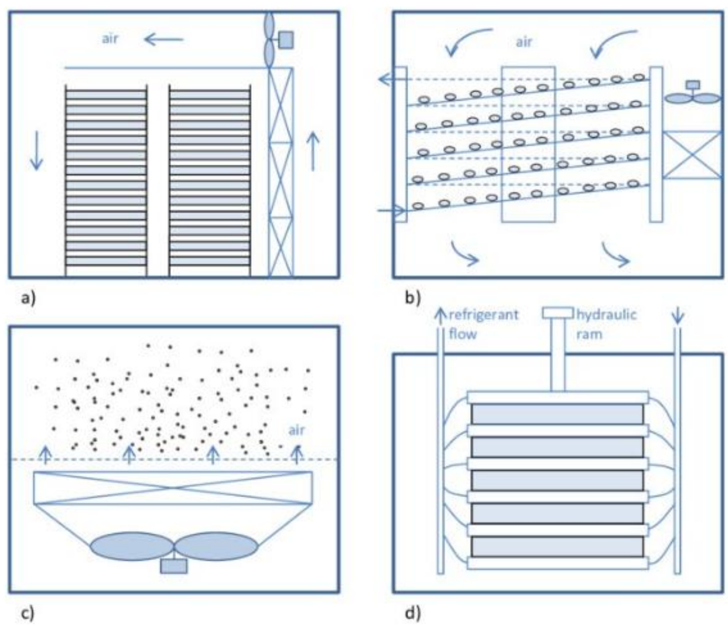

Fig 5.3 Different types of freezing equipment a) blast freezer, b) spiral belt freezer, c) fluidized bed freezer d) plate freezer

Source: Valentas et al., 1997, chap. 3

(2) Indirect contact with the refrigerant, where the food or package is in contact with the passage through which the refrigerant at −17.8 to −45.6 C flows, or (3) air-blast freezing, where frigid air at −17.8 to −34.4 C is blown across the materials being frozen. A method for the overseas shipment of frozen, packaged foods involves nitrogen freezing of the cartoned foods in a special aluminum case and ordinary storage on the ship. The original low temperature and the insulation guarantee that the food will remain in the frozen condition for the desired period. Certain fruits and vegetables, fish, shrimp, and mushrooms now are being frozen by means of liquid nitrogen. For **dehydrofreezing**, fruits and vegetables have about half their moisture removed before freezing.

The advantages claimed for quick freezing over slow freezing are that

(1) Smaller ice crystals are formed; hence there is less mechanical destruction of intact cells of the food,

(2) There is a shorter period of solidification and therefore less time for diffusion of soluble materials and separation of ice,

(3) There is more prompt prevention of microbial growth, and

(4) There is more rapid slowing of enzyme action. Quick-frozen foods, therefore, are supposed to thaw to a condition more like that of the original food than slow-frozen foods. This seems to be true for some foods, e.g., vegetables, but not necessarily for all foods. Research on fish, for example, has indicated little advantage for quick freezing over slow freezing.

5.4 GUIDELINES FOR TYPES OF FROZEN FOODS-FRUITS, VEGETABLES, FISH, MEAT AND POULTRY

In order to reduce the environmental impact of our consumption, packaging serves to protect and confine our products. It is a technology for enclosing or safeguarding goods for usage, sale, distribution, and storage. All food packaging materials must receive FDA approval before being used. Any material created with the goal of being used in food packaging needs to be formulated in accordance with FDA specifications. If a novel material is not currently regulated for the intended purpose, the maker must submit a petition to the FDA and present data demonstrating the material is safe to use.

Requirements for Packaging Depending on their physical, anatomical, physiology (primarily transpiration, respiration, and ethylene production rate), and susceptibility to microbial decay, various horticultural products require various types of packaging. The post-harvest life of fresh produce also depends significantly on temperature, relative humidity, and ventilation. Thus, the guidelines for packaging fresh produce can be summed up as follows: • Provide air for breathing and gas exchange • Protect against bruising and physical harm • Protect against microbiological contamination and deterioration • Prevent moisture loss and weight loss • Reduce the rate of respiration, postpone ripening, and lengthen storage time • Regulate ethylene concentrations in the package

Accidentally frozen cans, such as those left in a car or cellar in below-freezing temperatures, can cause health issues. The food might still be useable if the cans are very slightly swelled and you are certain that the swelling was brought on by freezing. Throw the cans away right away if any of the seams have rusted or burst. Throw away frozen cans that have thawed to temperatures exceeding 40 °F (4.4 °C). Before opening, let the unopened can defrost in the fridge. Throw away a product if it doesn't appear or smell as it should. Taste it not! If the product appears and/or smells normal, immediately boil the contents for 10 to 20 minutes to fully cook them. The products can then be stored or refrigerated for later use.

Food contact has been authorized by the FDA for packaging that is available for purchase or usage in grocery stores (such as produce or meat bags). These consist of: Polyethylene (PE), polyvinylidene chloride (PVDC), and polyvinyl chloride (PVC) are the three main types of plastics used to make consumer plastic wraps and storage bags. Petroleum derivatives are used in the plastic resins. It is possible to add plasticizers, colorants, or anti-fog substances.

In-store Produce bags are used to package fruits and vegetables for sale to consumers in-store. They are often constructed of polyethylene or another type of plastic film. Useless for cooking since the thin plastic could burn or melt.

Oven cooking bags - The bags' closure ties and material are both composed of heat-resistant nylon. They are suitable for use in normal ovens and microwaves with a maximum temperature of 400 °F (204.4 °C). Foil made of aluminum contains 98.5% of the material, with the remaining silicon and iron serving mostly as reinforcement and puncture resistance. Between big, water-cooled chill rollers, the molten alloy is rolled thin and solidified. Two layers of foil are run through the mill simultaneously during the final rolling. The side that comes into contact with the smooth steel rollers shines, while the opposite side becomes dull. Whichever side of the foil touches the food has no bearing.

Freezer paper is white paper that has had a plastic coating applied to one side to assist prevent freezer burn and moisture loss by keeping air out of frozen meals.

Parchment paper is a flavorless, odorless paper created from pure chemical wood pulps and/or cotton fibre. It is either greaseproof or grease resistant and can be coated or waxed. In baking, parchment paper is mostly used as a pan liner or to wrap food before cooking.

Wax paper A food-safe paraffin wax is pressed into the paper's pores and applied as a coating to the outside of wax paper, a triple-waxed tissue.

The FDA must approve packaging materials for irradiation in accordance with the Federal Food, Drug, and Cosmetic Act (FFDCA). It is impossible for the packaging to contain materials that could migrate into the food as a result of the irradiation process because it comes into direct contact with the food. Furthermore, after being exposed to radiation, these packaging materials cannot exhibit any discernible radioactivity. FDA guidelines outline a maximum absorbed dose level of radioactivity to which packing materials can be exposed without endangering food.

Poultry must be irradiated according to USDA/FSIS irradiation requirements in the package in which it will be marketed to consumers. There are only a few places in the United States where you can get irradiated poultry. Regulations for the irradiation of pork by the USDA/FSIS permit the irradiation of unpackaged pork because the radiation treatment kills the parasite trichinae, which is not airborne. Trichinae larvae would not likely contaminate the irradiated pork post-process. Currently, irradiated pork is not offered in the United States. In addition to the words "Treated with Radiation" or "Treated by Irradiation," the international symbol for irradiation, "Radura," can be found on the package of irradiated foods.

Fig 5.1 symbol for irradiation

The FDA has the authority to approve packaging materials that come into contact with food under the Federal Food, Drug, and Cosmetic Act (FFDCA). Go to "Packaging Materials for Irradiated Foods" in the Code of Federal Regulations, Title 21, Volume 3, Section 179.45 (referred to as: 21CFR179.45), updated as of April 1, 2013, for a comprehensive list of the packaging materials authorised for use in irradiation. www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm

5.5 PASTEURIZATION AND STERILIZATION FOOD IRRADIATION VACUUM PACKING CANNING AND BOTTLING

Pasteurization and Sterilization

Pasteurization is a process of heating a food, which is usually a liquid (milk), to a specific temperature for a predefined length of time and then immediately cooling it after it is removed from the heat. This process slows spoilage caused by microbial growth in the food. The French scientist Louis Pasteur invented pasteurization. To remedy the frequent acidity of the local wines he found out experimentally that it is sufficient to heat a young wine to only about 50–60 °C (122–140 °F) for a brief time to kill the microbes. Pasteurization of milk was suggested by Franz von Soxhlet in 1886.

Pasteurization was originally used as a way of preventing wine and beer from souring, and it would be many years before milk was pasteurized. This procedure accomplishes two goals at once: it eliminates harmful organisms connected to the food and increases the shelf-life of the product by reducing the microbial population and inactivating certain enzymes. The goal of the process, as well as the chemical and physical makeup of the food, will be taken into account when choosing the temperature and duration of pasteurization. Therefore, whole eggs (mixture of yolk and white) are pasteurized at 64.4°C for 2–5 minutes to prevent the spread of *Salmonella* spp., and milk is pasteurized at 62.8°C for 30 minutes to inactivate pathogens. - Inactivation of bacterial pathogens (target organisms *Coxiella burnettii*)

- Assurance of longer shelf life (inactivation of most spoilage organisms and of many enzymes)
- Does not kill all vegetative bacterial cells or spores (*Bacillus* spp. and *Clostridium* spp.)
- Pasteurization temperature is continuously recorded
- Pasteurised goods lack sterility. They include spores and vegetative creatures that can still grow. Many pasteurised foods require refrigeration to be stored.

Sterilization is a term referring to any process that eliminates or kills all forms of microbial life, including transmissible agents (such as fungi, bacteria, viruses, spore forms, etc.) present on a surface, contained in a fluid, in medication, or in a compound such as biological culture media.

Food Irradiation

Ionizing radiation used for food preservation is a recently invented technique; however, it hasn't yet found widespread popularity. It is common knowledge that electromagnetic radiations inhibit the growth of the majority of microorganisms. Since World War II, there has been a lot of research done on the potential applications of nuclear radiation in food sterilization. Many individuals have doubts regarding the safety of using irradiated foods due to the negative effects of radiation from nuclear explosions on the human body. There has been a lot of research on the wholesomeness and safety of irradiated foodstuffs, but more thorough studies are needed before irradiated food can be used on a large scale.

There are several kinds of radiant energy emitted from different sources, which differ in wavelength, frequency, penetrating power, and in the various effects they have upon biological systems. Irradiation of foods is carried out by exposing them to high-energy radiations which penetrate them and bring about changes within them. The principal radiations used in food irradiation are gamma rays (wavelengths<2A), emitted from excited radioactive elements (60CO), and accelerated negatively charged particles, electrons (P-particles), which are emitted from a hot cathode. Gamma rays are very similar to X-rays, except that they have much greater penetrating power. An electron beam can be accelerated to very high speeds and increased energies so that it can penetrate foods, by passing it through electronic devices.

Ultraviolet radiations are also employed in preservation; but they have a very low degree of penetration and are employed to inactivate micro-organisms on the surface of food and to treat air, water, and the surface of food processing equipment to reduce the number of micro-organisms.

A radiation source that is apart from the target material is used to expose it. Enthusiastic particles or waves are produced by the radiation source. These waves or particles collide with other particles when they enter the target material. Because energy is used up more quickly when collisions occur over a greater distance, the penetration depth of the irradiation process decreases. Chemical bonds are broken near the sites of these impacts, resulting in the creation of transient radicals (such as the hydroxyl radical, the hydrogen atom, and solvated electrons). These radicals alter the chemical composition of the surrounding molecules by connecting with them or removing their constituent parts. Cell collisions frequently decrease cell division, stopping or delaying the processes that lead the food to mature. Affected DNA or RNA makes it difficult for a microorganism to reproduce, which stops the spread of viruses and other species. The amount of radiation that is absorbed when it passes through food and is distributed differently depending on the density and energy of the food as well as the type of radiation employed. Originally, the common reference for a specific radiation dose was the term "rad," which stands for radiation absorbed dose. A rad is defined as the amount of radiation that results in absorption of 100 ergs of energy per gram of irradiated material (1 joule=107 ergs).

The radiation effects are related to dose by the relation:

n = *no* exp (-D / *Do)*

where *n* = the number of live organisms following irradiation; *n0* = initial number of organisms; D = dose radiation received (rads), and Do = a constant depending on type of organism and environmental factors.

However, this term "rad," has fallen out of use and has been replaced with the term "Gray" (Gy). A Gy is defined as 100 rads. So, when 1 kilogram (kg) of material absorbs 1 joule of energy, it is said to have received a radiation dose of 1 Gy. Doses are usually measured in the kiloGray, or kGy. which is equal to 1,000 Gy

Different organisms are sensitive to irradiation to different extent as indicated below: 103^ — 107 rads— micro-organisms are killed. 103 — 105 rads — insects are killed.

103 — IO4 rads — sprouting of potatoes, onions, carrots, etc., is inhibited. 102 — 103 rads — dose is lethal for humans.

The approximate sterilising dose for microorganisms is 3.0 x 106 rads for bacterial endospores and -5.0 x 104 rads for yeasts and fungi. But some microbes have exceptional resistance to radiation; for instance, *Micrococcus radiodurans* can withstand radiation doses up to 55 times higher than gram-negative organisms like *Escherichia coli*.

Ion pairs and free radicals are created when gamma rays and electron beams collide with food particles at the atomic and molecular levels. This happens when these ionizing radiations travel through foods. These products' interactions with one another and with other molecules produce physical and chemical events that render food-borne microorganisms inactive. This means that "cold sterilization" of food can be accomplished by irradiating food.

Types of Radiation Treatment

There are distinct radiation treatments that are utilized in the food industry today, even though the term "irradiation" refers to all methods of subjecting food products to ionising radiation.

Radurization: Radiation-based pasteurization is known as radularization. It is mostly used to treat foods with high pH levels and high-water activity levels. Typically, grain-negative psychrotrophs, which are primarily spoilage microbes, are the organisms that are targeted. The major food types for which this method is employed are meat and fish. Additionally, it can be used to combat mould and yeast in foods with low pH and water activity. About 1 kGy is the treatment dose for radurization.

Radicidation: The process of radicidation treats the food product to destroy pathogenic organisms on the product. This process only kills vegetative cells. This means that it will not kill spores that have been produced. The dose for radicidation ranges from 2.5 -5.0 kGy. Most vegetative cells are killed by this dose. However, some cells can survive. This includes some strains of the bacterium *Salmonella typhimurium.* These strains are said to be radiation-resistant. After the dosage has been administered, the product should be stored at or below 4°C to prevent any growth of spores from the *Clostridium botulinum organism.*

Radappertization: Radappertization is a process that is not recommended for most foods. It involves treating the product to levels of radiation of approximately 30 kGy. This high level of radiation kills all vegetative cells and also destroys spores from organisms, such as *Clostridium botulinum.*

Vacuum packaging and modified atmosphere packaging

The air's oxygen speeds up the chemical and microbiological deterioration of many foods. Scientists have created techniques to assist counteract the effects of oxygen in order to help keep meals longer. For instance, vacuum packaging creates a vacuum inside of containers by taking the air out of them. By substituting other gases, such as carbon dioxide or nitrogen, for some or all of the oxygen in the air inside the package, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) aid to preserve foods.

Controlling the oxygen levels in food packaging is crucial for reducing the rate at which goods deteriorate and perish. By adopting the vacuum packing technique, the air inside the pack is entirely evacuated by applying vacuum before the package is sealed, allowing the oxygen level to be controlled. Vacuum packaging, also known as skin packaging, involves entirely removing all of the air from the pack and retaining the food product under vacuum conditions, limiting the amount of oxygen accessible for the growth of microorganisms and oxidation. This method is especially helpful for fatty fish, where the main issue is the oxidation of fat, which leads to the production of unfavourable aroma.

Advantages of Vacuum packaging

- Reduces fat oxidation
- Reduces growth of aerobic microorganisms
- Reduces evaporation
- Reduces weight loss
- Reduces dryness of product
- Reduces freezer burn
- Reduces volume for bulk packs e. g. Tea powder, dry leaves etc.
- Extends the shelf life
- Easy to use and maintain the equipment

Disadvantages of Vacuum packaging

- Cannot be used for crispy products and products with sharp edges
- Requires high barrier packaging material to maintain vacuum
- Creates anaerobic condition, which may trigger the growth andtoxin production of Clostridium botulinum and the growth of Listeriamonocytogenes. Additional barriers / hurdles are needed to controlthese microorganisms
- Capital intensive

Use of packing materials with good barrier qualities is one of the key aspects of vacuum packaging. Typically, laminates made of polyester and polyethylene or nylon and polyethylene are utilised. Good strength and an effective oxygen barrier are provided by polyester and nylon. Polyethylene exhibits strong heat sealing ability and water transfer resistance.

A modified atmosphere (MAP) is one that has been made by changing the usual composition of air (which is 78% nitrogen, 21% oxygen, 0.03% carbon dioxide, and traces of noble gases) in order to create the ideal environment for extending the shelf life and improving the quality of food and goods. In MAP, oxygen, CO_2, and N_2 are most frequently employed. For usage in modified atmospheres, these gases are combined in three different ways: as an inert blanket using N_2, as a semi-reactive blanket using CO_2: N_2 or O_2: CO_2: N_2, or as a fully reactive blanket using CO_2 or CO_2: O_2.

Advantages of MAP

- The natural colour of the product is preserved
- The product retains its form and texture
- Reduces the growth of microogranisms
- Product retains its vitamins, taste and reduces fat oxidation
- The need to use preserving agents is reduced
- Helps in marketing products to distant locations
- Improved presentation –clear view of product
- Hygienic stackable pack, sealed and free from product drip
- Longer durability of perishable food / decrease of spoilage
- Extends the shelf life of fish in chilled / refrigerated storage by 2 – 3times
- Helps in reducing post-harvest loss

Disadvantages of MAP

- Capital intensive due to high cost of machinery
- Cost of gases and packaging materials
- Additional cost of gas analyser to ensure adequate gascomposition
- No control over the gas composition after packing
- Increase of pack volume which will adversely affecttransportation cost and retail display space
- Benefits of MAP are lost once the pack is opened or leaks
- High concentration of CO2 may favour anaerobiosis
- Strict maintenance of temperature has to be ensured to avoidthe risks of C botulinum and L monocytogenes.

Rigid or flexible containers that have had the majority of their air evacuated before being sealed. Nitrogen or carbon dioxide can be added to the container. This procedure delays bacterial development, protects flavours, and extends shelf life. The air's oxygen speeds up the chemical and microbiological deterioration of many foods. Scientists have created techniques to assist in counteracting the effects of oxygen in order to help keep meals longer. For instance, vacuum packaging creates a vacuum inside of containers by taking the air out of them. By substituting other gases, such as carbon dioxide or nitrogen, for some or all of the oxygen in the air inside the package, modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) aid in the preservation of foods.

Canning and Bottling

Placement of food in a sealable container, closure, heating, and cooling constitute the fundamental steps of canning. Although it was not until much later that the process was fully understood, this method of food preservation has been in use since the early 1800s. For preservation, large quantities of food are canned. Cans of food make up a sizable portion of the diet in developed nations. All canned foods include the majority of fruits and vegetables, a large range of meats and meat products, fish products, soups, and many other foods.

The following steps make up a standard canning process: Receiving, cleaning, sorting, and checking raw materials. 2. Blanching to render enzymes inactive. 3. Placing the product in the container with additional syrup or brine and deaerating it. 4. Heating in a retort with pressurized water for glass containers or steam for metal cans under a pressure of 1.05 kg/cm2. 5. Pressure-induced partial cooling in the retort. 6. Additional cooling in a cooling tank or using water jets. 7. Distribution, racking, and labeling.

Before canning, the raw product must first be evaluated for any necessary treatments. A lot of them need specific handling, including washing, trimming, shelling, size grading, and other processes. The majority of these processes are automated during commercial canning. The food can then be blanched to kill any enzymes and reduce surface contamination. The containers are filled with blanched food. In the case of vegetables, meat, and fish, brine (1.1 to 1.6 percent salt content) is added; in the case of fruits, syrup. Only water is added in some circumstances. Products made from fish frequently have oils added. Tin cans are often preferred for the majority of heat-processed foods. Glass jars are transparent, corrosion-free, and simple to clean, but they have the drawback of taking longer to process than cans of the same size. Additionally, there is the issue of breakage. Food canned in larger containers will be of inferior quality than food canned in smaller containers since heating time is roughly related to container volume and must be heated for a longer period of time. Instead, then using a container or jar to heat the food, try using a flexible, relatively thin pouch. Foods treated in this way have been shown to have a similar quality as frozen foods. The damage during distribution would be substantially less with pouches than with cans or glass jars because they can be heated for serving by simply submerging them in hot water. The importance of pouch canning is growing over time. The food container needs to be prepared for deaeration. This can be accomplished by heating the filled cans in steam or hot water or by using a vacuum closing machine, which removes the air with a pump and then seals the lid while maintaining vacuum. To avoid the can bulging owing to internal pressure, oxidation of the contents, and internal tin plate corrosion, air and gas must be removed. i. e. The sealed containers are heated in a retort, a room used for processing canned goods. Retorts come in a variety of forms. The most basic response is a still. Osmotic dehydration and canning/appertization have both been suggested as ways to enhance canned fruit preserves. On a small scale, the viability of an approach dubbed osmo-appertisation to achieve good quality fruit in syrup has been evaluated.

Aseptic canning: In normal canning, heat transfer from the outside of the container to the inside will require many minutes or even hours depending upon the container size to reach the sterilization temperature. The time of sterilization can be shortened to seconds or even a fraction of a second in aseptic canning. The basic principle of this method is that food is pumped continuously through a plate-type or tubular heat exchanger, which heats it very quickly to a high temperature, holding it at that temperature for the time required and then cooling. Food temperature employed may be as high as 150°C and sterilization takes place in 1 or 2 sees. Such a rapid sterilization at high temperature is referred to as ultra-high-temperature sterilization. The sterile food is quickly cooled, placed in aseptic containers, and the lids are sealed, while in a sterile environment. The food canned aseptically retains the nutrients and the sensory attributes will be good.

With acid foods, foods sterilized as in aseptic canning, while still hot, can be filled into clean but not necessarily aseptic containers. The heat of the food and some holding time before cooling the closed container renders the containers commercially sterile. This type of canning is known as "hot pack" or "hot fill."

With low-acid food (above pH 4.6), the conventional hot pack processing is not possible. In such cases, the *"flash 18"* process (pressure canning) is employed. Low-acid foods are heated above 100°C under pressure for sterilty. If food at that temperature is poured into containers for sealing at atmospheric pressure, there will be violent boiling. This is eliminated by carrying out the canning process in a chamber under a pressure of 1.05 to 1.40 kg/cm2. Thus, low-acid foods can be pre-sterilized by high temperature for a short time. They are then transferred to cans in a pressurized room and heated for an appropriate number of minutes so that commercial sterility of non-sterile cans is obtained, and finally the cans are sealed and cooled.

5.6 FOOD PACKAGING MATERIALS FOR PRESERVED FOOD PRODUCTS

Packaging is essential for food industry for inland and export markets. Thus, packaging forms an integral part in the chain of food production, transportation, storage and marketing and has important functions.

Some of the packaging materials are listed below

fresh fruit and vegetables – film bags, heat-sealed overwrapping film and container liners for bulk transport frozen fruit, vegetables, meat, poultry and fish products – film bags and heat sealed overwrapping films cereals – film bags sometimes with carton board outer packaging bread and bakery products – film bags milk, milk-based drinks, soups, fruit juices, and fruit drinks – HDPE bottles and polyethylene/carton board/polyethylene laminate containers long-life fruit juices and milk

- polyethylene/aluminium/carton board/polyethylene laminate containers yoghurt and other dairy products
- polyethylene/aluminium liddingtake-away foods and beverages
- polyethylene/paperboard/polyethylene laminate containers, and Coffee
- Polyethylene/aluminium/polyethylene terephthalate laminate bags.

Some of the common laminated films used for food packaging are listed below

- Polyvinylidene chloride-coated Crisps, snack foods, confectionery, ice
- polypropylene-polyvinylidene chloride cream, biscuits, chocolate confectionery coated polypropylene
- Polyvinylidene chloride-coated Bakery products, cheese, confectionery,
- polypropylene-polyethylene -dried fruit, frozen vegetables

- Polypropylene-ethylene vinyl acetate Modified atmosphere packaged -bacon, cheese, cooked meats
- Biaxially oriented polypropylene-nylon- Retort pouches
- Cellulose-polyethylene cellulose -Pies, crusty bread, bacon, coffee, cooked meats, cheese
- Cellulose acetate-paper-foil-polyethylene- Dried soups
- Metallized polyester-polyethylene- Coffee, dried milk, bag-in-box packaging, potato flakes, frozen foods, modified atmosphere-packaged foods.
- Polyethylene terephthalate aluminium propylene - Retort pouches
- Polyethylene aluminum paper Dried soup, dried vegetables, chocolate
- Nylon-polyvinylidene chloride polyethylene-aluminum-polyethylene- Bag-in-box packaging
- Nylon-medium density ethylene-butene copolymer- Boil-in-bag packaging

Glass bottles or cans with an open top should be used for packaging. Tomato juice should be hermetically sealed in glass or tinplate containers. The containers may be lacquered or plain, but should be of an acid-resistant variety if lacquered. It is generally ideal to leave some headroom so that the packaging can be opened and the contents can be poured without spilling. When the contents need to be shaken (like with flavored milk drinks and pulpy fruit juices), a headspace is crucial. For items like fruit juices, it is preferable to fill the space between the product and the top of the packaging with steam or an inert gas like N2.

A thin, rolled sheet of alloyed aluminium with a thickness range of 4 to 150 m is called aluminium foil. It was used to wrap chewing gum and Life Savers candy bars when it was first commercially made in the United States in 1913**.**

W.M. Martin invented the technology for cans in the late 1940s, and the James Dole Corporation in California ordered the first commercial aseptic filling equipment for soups in 1950. The cans and can ends are sterilised by this method using superheated steam at temperatures up to 225°C for up to 40 sec. This technique is compatible with the three common types of metal cans: tinplate, electrolytically chromium-coated steel (ECCS), and aluminum.

Hands on experience: Blanching of fruits & Vegetables Visit to Food Industries

5.7 LET US SUM UP

In this unit, we have learnt about what is low-temperature preservation along with various methods of freezing. Freezing is mainly important to inactivate or suppress the growth of microbes in the food. Different types of freezers with their functioning are discussed briefly. Much other preservation such as pasteurization and sterilization food irradiation vacuum packing canning and bottling are discussed briefly in this unit.

5.8 CHECK YOUR PROGRESS

Note: Use the spaces given below for your answers.

1) Discuss briefly the methods of Freezing types of freezers.

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2) What is aseptic canning?

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3) What is the difference between pasteurization and sterilization?

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4) What are the methods and safety regulations of food irradiation?

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REFERENCES BOOK

Norman N. Potter and Joseph H. Hotchkiss, 1995 Food Science, Fifth Edition, Springer

Some abbreviation

- ICAR: Indian Council of Agricultural Research.
- ICMR: Indian Council of Medical Research.
- CFTRI: Central Food Technological Research Institute, Mysore.
- CSIR: Council of Scientific and Industrial research.
- NDDB: National Dairy Development Board, Anand, Gujarat.
- CIPHET: Central Institute of Post Harvest Engineering and Technology, Ludhiana, Punjab.
- CIAE: Central Institute of Agricultural Engineering.
- APEDA: Agricultural Processed Food Products Export Development Authority.
- MPEDA: Marine Product Export Development Authority.
- NADC: National Cooperative Development Committee.
- IIHR: Indian Institute of Horticultural Research. (Kassargud, Bangalore).
- IISR: Indian Institute of Species Research.
- IVRI: Indian Veterinary Research Institute.
- NDRI: National Dairy Research Institute. (Karnal, Haryana). 100
- CPRI: Central Potato Research Institute.
- CTRI: Central Tobacco Research Institute.
- NRDC: National Research Development Cooperation.

- CIFT: Central Institute of Fishery Technology.
- FAO: Food and Agricultural Organization.
- IRRI: International Rice Research Institute.
- AICRP: All India Crop Research Products.
- PHT: Post Harvest Technology, ANGRAU, Bapatla.
- APFE: Agricultural Processing and Food Engineering.
- UAS: University of Agricultural Sciences, Bangalore.
- CPCRI: Central Plantations Crop Research Institute, Trivandrum.
- NHB: National Horticultural Board.
- MOFPI: Ministry of Food Processing Industries.
- FPO: Fruit Product Order.
- HACCP: Hazard Analysis Critical Control Point.
- BIS: Bureau of Indian Standards.
- PFA: Prevention of Food Adulteration Act.
- Ag mark: Agricultural Marketing Inspection.
- GDP: Gross Domestic Product.
- WHO: World Health Organization.
- FDA: Food and Drug Administration.
- GMP: Good Manufacturing Practices.
- TQM: Total Quality Management.
- DOFPI: Department of Food Processing Industries.
- PCB: Pollution Control Board.
- PRRC: Paddy Processing Research Center.
- CIDA: Canadian International Development Agency.
- NABARD: National Bank for Rural Development.
- SSCA: State Seed Certification Agency.
- MMPO: Milk and Milk Product Order.

UNIT VI: ADDITIVES AND PRESERVATIVES

Structure:

6.0. Introduction

6.1. Acidulates

6.2. Chelating Agents

6.3. Antimicrobial Agents

6.4. Stabilizers and Thickeners

6.5. Fat Replacers

6.6. Firming Texturizers

6.6.1. Chloride of Calcium

6.6.2. Calcium Phosphates

6.6.3. Konjac

6.6.4. Sulphate of Calcium

6.7. Appearance Control and Clarifying Agents

6.8. Flavor enhancers

6.9. Aroma substances

6.10. Sugar substitutes:

6.10.1. Sweeteners

6.10.2. Healthy sweeteners

6.10.3. Artificial sweeteners

6.11 Antioxidants

6.12 Anti caking agents

6.13 Protective Gases

6.14 Lets Sum Up

6.15 Check Your Progress

6.0. INTRODUCTION

Since ancient times, food additives have been utilized to improve the quality of food products. More than 10,000 years ago, foods were preserved with the help of smoke, alcohol, vinegar, and spices. Additionally to advancements in food chemistry in the early 1900s, the usage of food additives greatly grew for food preservation. The demand for novel, delectable, practical, and nourishing foods was rising. As a result, by the early 1960s, several developed nations were using more than 2500 distinct chemicals in food.

Various individuals used to understand food additives in various ways. A material or combination of substances, other than a fundamental food, that is present in a food as a result of any part of production is generally acknowledged as a food additive. Food additives are compounds that are consciously introduced for particular purposes. Currently, a relatively significant number of additives are utilized in food. Although they can be divided into a few groups according to their functional characteristics-Preservatives, antioxidants, acidulates, neutralizers, and buffers, coloring agents, flavoring agents, and sweeteners are a few examples of possible additives ,nutritional additives, and other additives.

Although widely recognized, the use of food additives is not without debate. Concerns have been raised about the potential short- and long-term dangers of ingesting these drugs. Concerns have been raised about the potential short- and long-term dangers of ingesting these drugs. The maximum allowable limits (Acceptable Daily Intake, ADI) of additives have been established based on the scientific data currently available on the toxicological status of each additive and the likely quantity of that ingredient consumed through a particular meal. As you will see in later courses, every nation has established its own food laws. For example, India's Prevention of Food Adulteration Act (PFA) and Rules, 1954, outlines the additives that are allowed in various foods as well as the highest authorized levels. Additionally, you will learn that our food standards are being synchronized with other countries' food standards. As a result, it is anticipated that the current list of authorized chemicals under PFA will grow soon. Keeping these things in mind, various significant and useful food additives are covered in this unit, even though some of them might not currently be covered by PFA. Vitamins and minerals, which are nutritious supplements, have already been discussed in the previous unit; they will not be covered in this one.

6.1. ACIDULANTS

Many of the functional qualities that acidulates bring to the table improve the quality of food. Organic acids are utilized as the majority of food acidulates. Acetic, ascorbic, citric, lactic, malice, and tartaric acids are among the organic acids and salts that are frequently employed in meals. Additionally, phosphoric acid and other inorganic acids are frequently utilized in cola-style drinks. Pants commonly include organic acids like citric, malice, and tartaric acids. Vitamin C, or ascorbic acid, also comes from plants. As the name suggests, lactic acid comes from milk. Acetic and ascorbic acids aren't specifically described here because several parts of them have already been covered elsewhere.

The most common organic acid is probably citric acid. It is a tricarboxylic acid that can be found in large quantities in citrus and other fruits. Although citrus fruits were once used to make it, most commercial citric acid is now made through fermentation. White crystalline powder, or citric acid, is readily soluble in water. The monohydrate of citric acid is offered for sale commercially. Its nature is hygroscopic. Citric acid is therefore not a great choice for use in dry food compositions.

Malic acid is a dicarboxylic acid called 2-hydroxybutanoic acid. It is the primary acid found in mangoes and apples. It is a white, crystalline powder that dissolves quickly in water. Commercially, synthetic malic acid is offered. Malic acid is flavored for use in dry food compositions since it is non hygroscopic.

Another dicarboxylic acid is tartaric acid. It is the main acid found in tamarind and grapes. Additionally, it is a water-soluble white crystalline solid. Typically, it is isolated from the argol sediment that results from the fermentation of grapes.

Baking powder and fizzy 'health salts' both use tartaric acid.

Common uses for acidulates

The right acid choice will depend on the desired acid property or qualities and a mix of those traits, as well as the acid's price. Below are some of the general functions.

- Flavoring substances they hide unpleasant tastes while enhancing some flavors and sensations.
- Buffering action: Organic acid salts, particularly sodium salts, regulate the pH of food at different stages of processing as well as in the final product.
- Preservation: By lowering pH, you can avoid food spoiling and food poisoning by stopping the growth of microbes and the germination of spores.
- Sequestering: Bind metal ions and improve antioxidant performance.
- Viscosity modifiers: Similar to those found in dough, they alter the shape and texture of baked goods.
- Meat curing agent: Enhances color, flavor, and preservation action when combined with other curing ingredients.

The majority of food acidulates are legal under PFA with some limitations.

6.2. CHELATING AGENTS

Chelating agents are food additives that extend the shelf life of baked goods by preventing oxidation. Metals are trapped by them, preventing them from contributing to colour or flavor deterioration. Chelating agents are organic compounds having a ring-like centre that, when combined with a mineral ion, form at least two bonds, or what is known as chelates, which are complicated structures.

Examples of these are:

- EDTA, or ethylenediamine tetraacetic acid
- Polyphosphates
- such as tartaric or citric organic acids

Function

The Greek word "chele," which signifies a crab's claw, is where the word "chelate" comes from. Chelating agents must have two specific qualities in order to function:

1. Two distinct binding locations for the metal it chelates.
2. Ability to work in concert with the metal ion to form a ring.

Metals can interact with food system components or serve as cofactors for enzyme activity. Examples include calcium, zinc, iron, copper, and many others. Chelating chemicals can postpone or slow down these processes by binding to metals, protecting the functional and sensory qualities of food products. Some chelating substances can also work well as antioxidants. For instance, the most well-known chelating agent is EDTA. Most commonly, calcium disodium EDTA, disodium EDTA, tetrasodium EDTA, and other EDTA salts are generated. Several typical varieties in baking:

1. The most well-known chelating agent, ethylenediamine (EDTA), is a multi-dentate molecule because it may create two distinct bonds.

2. Disodium pyrophosphate is produced when phosphoric acid and sodium carbonate interact chemically, resulting in sodium phosphate, which then needs to be heated further to produce disodium pyrophosphate. Disodium pyrophosphate's main use in baking is as a source of acid that can be used to combine with baking soda to produce leavening. Due to the creation of carbon dioxide gas during fermentation, which creates air pockets within the crumb and the evaporation of alcohol, leavening promotes rise in the product. The ability of the baked goods to retain more water, which results in enhanced moisture and extended shelf life, is a second function.
3. The chelating property of phosphoric acid prevents oxidation brought on by metal ions.
4. Citric acid: Has the ability to maintain scent and decrease the rate of discoloration. Fruit fillings in pastries and other baked goods use it as a preservative.

Natural chelating substances

The quest for substitute clean-label compounds has been motivated by the synthetic origin of EDTA and its non-biodegradable nature such as:

- Chlorella
- Glycine
- Food-Grade Activated Charcoal

None of these, however, has been utilized to successfully replace EDTA.

6.3. ANTIMICROBIAL AGENTS

Since many years ago, it has been recognized that bacteria can create antimicrobial compounds (antibiotics). However, only recently have some of these chemicals been approved for use in food. In some dishes, nisin and natamycin are authorized. Steptrococcus lactis, now known as lactococcus lactis, is a polypeptide producer. The pH of the medium affects the compound's solubility. In neutral pH, it is practically insoluble, and it is more soluble in acidic pH .

Only gram-positive bacteria, such as lactic acid bacteria, streptococci, bacilli, and clostridia are affected by the restricted spectrum of nisin. Gram-negative bacteria, yeasts, and molds are typically not inhibited by it. Nisin has a pH-dependent antibacterial effect that is stronger as the pH drops. It works at extremely low doses of 0.04 to 2.0 ppm.

Under PFA, nisin is permitted in canned rasagolla and packaged coconut water. Streptomyces natalensis is the bacterium that makes natamycin. The substance has a sizable lactone ring that is replaced by one or more sugar residues. Ineffective against bacteria, viruses, and actinomyces, natamycin is largely effective against yeast and mould. Additionally, natamycin works well at very low concentrations of 5–10 ppm. Hard cheese surfaces may now be treated with natamycin.

6.4. STABILIZERS AND THICKENERS

Consumers expect specific levels of quality and gastronomic satisfaction from processed meals. Stabilizers, thickeners, and gelling agents, which give food a consistent texture, flavor, and mouth feel, help to achieve this in part.

a. Definition

Stabilizers, thickeners, and gelling agents are permitted direct food additives that are extracted mostly from natural sources and added to foods to give structure, viscosity, stability, and other properties including maintaining current color.

b. Labeling, Names, and Functions

Although thickeners, stabilizers, and gelling agents are each given their own classification, their functions are similar. They produce rigidity, stabilize emulsions, or create gels when they are dissolved or added to food.

Thickeners are chosen for their versatility in a range of chemical and physical circumstances. They can be flavorless powders or gums. The pH, frozen state, clarity, and taste of the thickener can all be influenced by many factors. The most often used commercial thickeners in soups, sauces, and puddings include starches, pectin, and gums.

Stabilizers are compounds that assist meals stay in an emulsion and preserve their physical properties, increasing stability and thickness. Stabilizers are necessary for ingredients like oil and water that don't often combine. Stabilizers are necessary for many low-fat foods. Ice cream, margarine, dairy products, salad dressings, and mayonnaise frequently contain lecithin, agar-agar, carrageen an, and pectin.

In jellies, jams, sweets, yoghurt, and candies, gelling chemicals also serve as stabilizers and thickeners to offer thickening without rigidity. Common gelling agents include gums, starches, pectin, agar-agar, and gelatin.

With the inclusion of well-known starches, cereals, egg yolks, yoghurt, gelatin, mustard, and vegetable purees, home cooking produces the same structural alterations.

To facilitate swallowing and lower the danger of aspiration, thickening agents are also used to treat medical problems including dysphasia.

Food labels provide a classification, such as "pectin (gelling agent)," to help consumers understand the purpose of the food additive. The majority of direct additions are listed on food ingredient labels. Most polysaccharides and protein-based thickeners, stabilizers, and gelling agents come from sources like:

Polysaccharides

- arrowroot, corn flour, potato starch, sago, and tapioca starches
- Guar gum, extracted from guar beans, xanthan gum, derived from microbial fermentation, and locust bean gum, derived from carob trees, is examples of vegetable gums.
- Pectin (from citrus or apples)
- Gelatin (made from animal collagen), egg whites, collagen, and whey
- Other sugars include agar (made from algae) and carrageen an (made from seaweeds and used to stop dairy products including ice cream from separating).
- Sodium pyrophosphate, a chemical found in many everyday goods including canned salmon and instant pudding.
- Lecithin (found in maize, beans and egg yolk)
- (Stabilizers that are naturally present in many seed oils: mono- and diglycerides)
- In addition to being predominantly natural (carboxymethyl cellulose, methyl cellulose),

sources can also be manufactured (arrowroot, gelatin, starches).

Oversight

- Before usage, thickeners, stabilizers, and gelling agents must have Food and Drug Administration approval. Food additives must meet tight criteria and strict standards in order to be approved, and there must be a legitimate reason for their use.
- Depending on the additive and the meal it is used in, there are different maximum usage levels.
- For instance, stabilizers cannot make up more than 0.5 percent of the final weight of frozen dairy desserts, fruit and water ices, confections, and icing. The maximum allowed amount of emulsifier, adjuvant flavoring, stabilizer, or thickening in baked goods is 0.5 percent by weight.

Safety

Food additives are subject to more scrutiny, regulation, and oversight today than ever before. To reduce potential negative impacts on human health, all new food additives go through extensive testing and safety evaluation. Large amounts, however, may cause adverse reactions and nutrient-drug interactions. For instance, eating more than 15 grammas of xanthan gum may make you queasy, bloated, and flatulent. It is possible for foods and medicines to interact. Carrageenan and pectin both have the potential to have negative side effects on those taking anticoagulants and antihypertensive medications.

6.5. FAT REPLACERS

- Nonfat ingredients called "fat replacers" mimic the effects of fat in diet. A material that tastes and looks like natural fat but contains less calories would make the perfect fat substitute because it poses no health dangers. Foods including cheeses, sour cream, yoghurt, margarine, salad dressing, sauces, and gravies all contain fat substitutes.
- There are three main categories for fat substitutes:
- Carbohydrate-based. These are produced using starchy ingredients including corn, grains, and cereals. Today's fat substitutes are typically manufactured from carbohydrates. Dextrins, gums, cellulose, gelatin, and modified dietary fibres are a few examples.
- Protein-based. These are produced by altering protein using egg whites or milk whey. Whey protein, microparticulated egg white, and milk protein (like Simplesse) are other examples.Fat-based. In place of triglycerides, they are created in vegetable oils. Caprenin, salatrim (found in Benefat), and olestra (found in Olean) are a few examples.
- It may be difficult for consumers to detect fat replacers in the meals they purchase because their brand names aren't always featured on the ingredient label. If you decide to utilize fat substitutes, consider the following:
- Protein- and carbohydrate-based fat substitutes don't harm health, according to recent research.
- Olestrá, a noncaloric fat replacement, prevents the body from absorbing fat-soluble nutrients such carotenoids and the fat-soluble vitamins (A, E, D, and K). Plants include pigments called carotenoids, which act as antioxidants in your body. Carotenes and lycopene (found in tomatoes) are two examples. Cramping, bloating, and loose stools are olestra's side effects.

- Compared to foods that include fat, those with fat substitutes may have fewer calories. However, some individuals could have a tendency to consume more of the replacer-containing meal, making up for the lost calories.
- More study is required on fat substitutes. Speak to a certified nutritionist about adding fat substitutes to your diet.

6.6. FIRMING TEXTURIZERS

The addition of firming agents strengthens the supporting tissue and prevents collapse during processing by precipitating residual pectin. Pectin is a naturally occurring substance found in fruits and vegetables that forms a stiff gel around the fibrous tissues of the fruit to prevent it from collapsing. When calcium salts are added, calcium pectate gel forms, supporting the tissues and providing protection from softening during processing. In the form of a tablet containing both sodium and calcium chloride, the calcium salt is occasionally added to the canned vegetable.

To keep them from softening and disintegrating during processing, canned vegetables, canned apples, frozen apples, and tomatoes are occasionally given a calcium chloride, calcium citrate, monocalcium dihydrogen phosphate, calcium lactate, or calcium sulphate treatment. The recommended level of use for these calcium salts, measured as calcium in the finished food product, is 0.02%. Calcium chloride and calcium citrate are used in canned potatoes at a level of 0.5% (calculated as calcium).

Pickles and relishes use acidic aluminium salts such sodium aluminium sulphate, potassium aluminium sulphate, ammonium aluminium sulphate, and aluminium sulphate as firming agents. Aluminium sulphate, a more contemporary firming agent, is used in canned crab, lobster, salmon, shrimp, and tuna.

Below, significant firming agents are addressed.

6.6.1. Chloride of calcium

Calcium chloride is used as a firming agent in canned vegetables, the process of turning soy bean curds into tofu, and the creation of a caviar alternative from fruit or vegetable liquids. It works with gelling chemicals to reinforce food structure or helps keep fruits and vegetables solid. The firming agent in cheddar and cottage cheese is calcium chloride.

In sensitive individuals, calcium chloride may cause stomach irritation.

6.6.2. Calcium phosphates

Hydrated lime and phosphoric acid combine to produce calcium phosphates under carefully controlled circumstances that maximize the production of the desired product.

In order to strengthen the firmness of canned vegetables like carrots and tomatoes and to improve the structure of low-gluten flours, monocalcium phosphate is employed as a calcium source.

6.6.3. Konjac

- The tuber of the Amorphophallus konjac plant is where konjac gum and konjac glucomannan, sometimes referred to as konjac flour, yam flour, konnyaku glucomannan, and glucomannan gum, are extracted.
- Konjac gum, kappa, and carrageenan are used in 0.6% of table dessert gels and aspics to produce solid, cohesive textures. In coarse-ground meat and sausage imitations, the thermally stable glucomannan gel is used as a water binder and texture enhancer.

- Aspics, surimi, frozen sweets, sauces, and batters are examples of typical items.

6.6.4. Sulphate of calcium

- Plaster of Paris is another name for the naturally occurring mineral calcium sulphate.
- In order to add the calcium and sulphate ions that are found in naturally hard water, calcium sulphate is used to prepare water for brewing.
- It is also utilized to supply calcium ions to natural cell-wall pectin in canned fruit and vegetables, which reacts to maintain the pieces' firmness. It increases cell strength and bubble stability during baking.

6.7. APPEARANCE CONTROL AND CLARIFYING AGENTS

- Clarifying agents are those who bring about clarification. Clarifying agents are used to get rid of some solids that give liquids a foggy appearance.
- Beer, carbonated beverages, etc.
- Clarifying chemicals are what give these drinks their dazzling clarity.
- Fruits contain pectin, a complex carbohydrate. It creates a fibrillar network in three dimensions. When cereal malt is used as a foundation, pectin, fibrous tissue, and certain hemicelluloses must be removed since they give beverages a muddy look. Clarifying chemicals are employed to create clarity.

Natural Agglutinants:

1. Activated carbon: Some of the suspended particles can be removed through adsorption.
2. Gelatin, which is made from animal collagen a protein that is positively charged however, because it discolors food, tannins are added as well. For instance, apple juice with cashews. The juice's colloids coagulate to form a flocculent precipitate, which settles. It is brought on by the electrostatic attraction between the negatively charged pectin and positively charged gelatin colloids. Between the phenolic group in juice and the peptide group in gelatin, hydrogen bonds are created.
3. Albumin: made from egg whites and juice cooked to 910 c. Albumin (2%)
4. Casein: A 2% casein solution is added, and after 24 hours, the casein precipitates from the juice's acids.
5. Tannin and Gelatin Combination: Tannin is used to lessen the bleaching effect of gelatin. Then, clear juice is separated using a syphon.

Clarification is achieved using certain enzymes.

- Filtragol
- Pectinol

Pectin's are broken down by pectin methyl esterase, a type of pectin-digesting enzyme. In addition, physical techniques like freezing and heating can be applied.

6.8. FLAVOUR ENHANCERS

Food flavor and color both have a significant impact on consumer acceptance, and as a result, are of huge commercial significance. Despite some research suggesting that taste can affect intestinal absorption of glucose and fat metabolism, it appears to have little nutritional value. There are various definitions for flavor. "Sensation produced by a material taken in the mouth, perceived primarily by the senses of taste and smell, as well as by general pain, tactile, and temperature receptors in the mouth," is one definition.

The topic of food flavors is fairly broad. In a following unit, you will study flavour analysis and sensory experience. You will discover some crucial information on the chemistry and use of food flavorings in this section. In the beginning, spices were employed to improve or alter the flavor of food. A surge in synthetic taste chemicals and their identification in various foods and processed goods occurred along with advancements in synthetic chemistry and analytical methods like gas chromatography and mass spectrometry. Techniques for sensory analysis play a big part in flavor research. One significant discovery was that very sometimes did a single chemical compound account for the distinctive flavor of a dish; instead, the majority of food odors were the result of a mixture of several chemical compounds. Menthol in peppermint, benzaldehyde in bitter almond, citral in lime peel, and amyl acetate in ripe bananas, cinnamon, and others are a few examples.

It became clear that developing a food flavor is a difficult process as a result. However, a wide variety of flavor compositions are now available thanks to a combination of artistic and scientific knowledge. It is a very sizable industry. Three groups make up the classification of food flavorings.

- Natural flavors and natural flavoring ingredients are flavor mixtures and single ingredients, respectively that are suitable for human consumption. They are obtained solely through physical means from raw vegetable and occasionally animal materials, either in their natural state or after processing, for human consumption.
- Flavoring ingredients that are chemically equivalent to those found in naturally occurring items intended for human consumption, whether processed or not, can be produced synthetically or chemically separated from aromatic source materials.
- Artificial flavoring ingredients are those in natural goods intended for human consumption that have not been identified, whether they have been processed or not.

- Spice oleoresins and oils, essential oils like citrus oils, fruit aroma concentrates like apple aroma concentrate, etc. are some examples of natural tastes. As was already said, there is a tone of synthetic flavoring agents.
- Therefore, only those flavoring chemicals that are prohibited by PFA are listed, rather than the approved flavoring substances. In this context, it's crucial to remember that natural or artificial flavors require extremely low concentrations of flavor chemicals—on the order of parts per million or parts per billion—to impart the required flavor perception. Due to their self-limiting nature, maximum allowable limitations are not applicable to them.

6.9. AROMA SUBSTANCES

- Vegetables, herbs, and spices that give aroma and flavor to food are known as aromatics. Use a variety of aromatic combinations when preparing foods from other cuisines. The vegetables, herbs, and spices that chefs utilize as the base of a dish's flavor are referred to as aromatics. For sauces and stir-fry recipes, sauté aromatics in butter or oil at the start of the cooking process. You may also wrap aromatics into a sachet and simmer them in liquid to make broth, stock, or soup. Different cuisines use different aromatic combinations as the foundation for flavor.

- In cuisine, there are three primary categories of fragrant ingredients:
    - Herbs: Both fresh and dried herbs can be used as aromatics. Herbs can be divided into two categories: sensitive herbs commonly referred to as soft herbs, and hard herbs. Tender herbs, such as cilantro, chives, tarragon, parsley, dill, mint, and basil, have soft stems and leaves. Hard herbs have tougher leaves and hard, woody stems. Popular hard herbs include sage, bay leaves, ginger, galangal, lemongrass, oregano, thyme, and fennel.
    - Spices: Whole and ground spices are common aromatics as well, especially in Asian and Indian cuisine. Chili peppers, cumin, coriander, cardamom, turmeric, paprika, and other spices have strong aromas.
    - Vegetables: To start off the cooking procedure, sauté some fresh vegetables in butter or cooking oil. Onions, shallots, scallions, celery, garlic, carrots, leeks, and bell peppers are some common fragrant vegetables. Dice the vegetables for quick preparations, and use large chunks for slow-cooking dishes like stock.

The Use of Aromatics in Cooking

For stews, braises, stir-fries, and soups, aromatics serve as the foundation. Take into account the following fragrant pairings for varied cuisines:

1. The holy trinity of sliced carrots, onions, and celery sautéed in butter or oil is referred to as "mirepoix" in French. Many well-known French and American meals, like boeuf bourguignon and chicken noodle soup, start with mirepoix as their foundation.
2. Sauté carrots, onions, and celery in olive oil to make soffrito, an Italian take on mirepoix
3. To prepare bolognese, lasagna, and other Italian soups and stews, home cooks utilize soffritto.
4. Cajun: Onions, green bell peppers, and celery are often sautéed in butter or oil to create the fragrant base for many Cajun meals like gumbo and jambalaya.
5. Spanish: A flavorful sauce called sofrito is made in Spain with tomato paste, garlic, bell peppers, cilantro, parsley, and various spices. To intensify the flavors that may be added to meals like paella, empanadas, and stews, this tasty base is slowly simmered in olive oil. In Latin America, there are various regional sofritos; the cuisines of the Dominican Republic, Puerto Rico, and Brazil all offer distinctive varieties.

Depending on the location, cooks may add other aromatics, like dried chilies in Sichuan cuisine.

6. Thai: Shallots, garlic, and chilies form the foundation of Thai cooking. (Coconut milk is a component of curry recipes). Galangal, lemongrass, and kaffir lime leaves are some more ingredients that are frequently used to flavor food.
7. Indian: Curries, meat, and vegetable dishes of Indian cuisine use a variety of spices. Indian cooking typically starts with the heating of spices like cumin, cardamom, turmeric, and cloves in ghee or oil. Along with the aromatics, frequent flavorings include tomatoes, onions, ginger, and yoghurt.

6.10. SUGAR SUBSTITUTES

6.10.1. SWEETENERS

- One of the essential tastes is sweetness. The massive production of sugar (sucrose) worldwide is a reflection of the value of sweetness. Sucrose is taken for reasons other than sweetness. It also has numerous useful such as a bulking agent, texture altering agent, and preservative.

- Like all other carbohydrates, sucrose is a food that gives the body energy. The developments of obesity, disorders that are related to it, as well as dental cavities, have all been linked to sugar throughout time. In addition, diabetes has spread to affect significant portions of the population. As a result, there is a general tendency to consume less energy. This led to the creation of sucrose substitutes. There are two categories of sweeteners to choose from: nutritive and non-nutritive. Carbohydrates or their derivatives—also known as calorie sweeteners—usually make up nutritional sweeteners. A variety of organic ingredients as well as some artificial compounds makes up non-nutritive sweeteners.

Artificial sweeteners

- In a previous unit, you previously learned about the relative sweetness of glucose, glucose syrup, fructose, and high fructose corn syrup. You will learn about a few different healthy sweeteners in this section.
- **Sorbitol:** A six-carbon sugar alcohol known as sorbitol was first discovered in the berries of mountain ash. It is made chemically from glucose for use in industry. At 25 °C, it is quite water soluble (72%). The sweetness of sorbitol is half that of sucrose.
- Sorbitol is used as a sweetener for diabetic meals, sugar-free chocolates, and chewing gum since it has fewer calories than sucrose.
- **Xylitol:** The majority of fruits and berries as well as plant materials that contain the polysaccharide xylan contain xylitol (also known as xylit), a pentiol. Additionally, it is made via microbiological processes. The crystalline compound xylitol has high water solubility (64 percent at 25 °C). Similar to sucrose in terms of sweetness and calorie content.
- However, unlike glucose or sucrose, xylitol absorbs slowly, therefore it does not raise blood sugar levels. As a result, it is also utilised in foods for diabetics.
- Hydrogenated isomaltulose is another name for isomalt. 6-0-D-glucopyranosyl-Dglusitol and 1-0-D-glucopyranosyl-Dmannitol are mixed in an equimolar ratio. Enzymatic transglucosidation of sucrose to isomaltulose and hydrogenation result in the production of isomalt. Its sweetness is around half that of sucrose.
- When used in food processing under typical conditions, it is stable in both acidic and alkaline media. It doesn't affect blood sugar levels. In candies, gum, soft drinks, and desserts, isomalt is used in place of sugar.

6.10.3. Artificial sweeteners

- The synthesis of saccharin took place in 1879. Due to the shortage of sugar during the two world wars, saccharin's use as a sweetener increased. Despite repeated concerns about its safety, saccharin became a common sweetener for specialized dietary and dietetic items.
- Sodium saccharin, calcium saccharin, and saccharin are all referred to as saccharin collectively. Saccharin is 1,2-benzisothiazol-3 (2H)-one-1, 1-dioxide chemically speaking.
- White crystalline powders, sodium saccharin and saccharin, are soluble in water.
- They have a 500-fold greater sweetness than sucrose. It maintains good stability when food

products are being cooked and baked, however it has a little metallic aftertaste. With limitations, it is legal to use as a sweetener in several nations, including India.

- The available toxicological evidence does not definitively link saccharin to any major health risks. Saccharin's Acceptable Daily Intake (ADI) is set by the WHO at 2.5 mg/Kg body weight. However, as more and more study findings mount, safer substitutes for saccharin are certain to appear.
- Cyclamates: Although sodium cyclamate was first synthesized in 1937, it wasn't until 1950 that it was first used as a sweetener. Cyclamic acid, sodium cyclamate, and calcium cyclamate are all referred to as cyclamates. By sulphonation, they are produced from cyclohexylamine. In nature, they are not to be found.
- Cyclamates are easily soluble in water and stable at high temperatures. They can be utilized as a noncalorie sweetener in a number of goods and are approximately 30 times sweeter than sucrose. It may occasionally be used with saccharin.
- Cyclamates raise several safety concerns. Therefore, much like with most other non-nutritive sweeteners, its use is only permitted under certain conditions. Under PFA, cyclamates are not allowed to be used. It has an ADI of 11 mg/Kg of body weight.
- Aspartame: This sweetener was only identified in 1960. It is L-aspartyl-L-phenylalanine's methyl ester. The amino acids phenylalanine and aspartic acid are used to make aspartame. It is a flavorless, white, crystalline powder that is around 150–200 times sweeter than sucrose and just marginally soluble in water.
- Aspartame has 4 Kcal of energy per gramme. Aspartame gives meals sweetness similar to sugar, but when it is exposed to particular moisture, temperature, and pH levels, it hydrolyzes and loses its sweetness. As a result, despite its widespread use in soft drinks, dairy products, and other items, aspartame is better suited for dry goods or as a tabletop sweetener. The typical sweetener for soft drinks is a combination of saccharin and aspartame.The information that is now available suggests that aspartame usage in moderation is safe because it is consumed at levels that are well below any potential dangerous threshold. The ADI for it is set at 40 mg per kg of body weight. In a lot of nations, including India, aspartame use is legal.
- Acesulfame K: Acesulfame K was one of the non-nutritive sweeteners that was first released in 1967. The potassium salt of 6-methyl-1, 2, 3-oxathizine-4(3)-one-2,2-dioxide is acesulfame K. It is a 150–200 times sweeter substance than sucrose that is a white, crystalline powder that is freely soluble in water and not hygroscopic.
- Acesulfame K is a tabletop sweetener as well as an ingredient in soft drinks and gum. There are other food applications being looked upon.
- The existing toxicological information on acesulfame K does not indicate any significant safety concerns. The set ADI value is 9 mg/Kg of body weight. In some nations, like India, its usage as a sweetener is approved with restrictions.

6.11. ANTIOXIDANTS

- Antioxidants are crucial for keeping fats, oils, and fatty meals fresh. You already know how oils and fats work chemically. They are essentially glycerine's fatty acid esters. There are two types of fatty acids: saturated and unsaturated.

- During storage, the unsaturated fatty acids in fats and oils may be subject to oxidation, which can result in the formation of rancidity. Along with the development of rancidity, nutrient depletion, coloration, and even toxic consequences are potential side effects.
- The term "autocatalytic reaction" is frequently used to describe lipid oxidation. It is a complicated reaction that, once it starts, will spiral out of control. The autoxidation reaction, which is essential to glyceride oxidation, can be inhibited or interfered with by foods that include antioxidants. Simply said, they undergo oxidation instead of fats and oils.
- You probably know that tocopherols, which are found in a variety of vegetable oils, have antioxidant properties. Lecithin and ascorbic acid both have antioxidant qualities. However, phenolic compounds—often referred to as phenolic antioxidants—are the main antioxidants commercially employed in foods, fats, and oils. Foods may include some metals like iron and copper, which are potent fat oxidation catalysts and may interact with antioxidants to discolor food. Food acids with the ability to bind these metals include citric acid.
- As a result, the antioxidants are frequently added in addition to citric acid. The four most commonly utilized phenolic antioxidants for fats and oils are tert-butyl hydroquinone (TBHQ), butylated hydroxy anisole (BHA), and butylated hydroxy toluene (BHT).
- Butylated hydroxy anisole (BHA) is a solid that is white and waxy and is typically tableted to prevent caking while being stored. It has a pronounced phenolic aroma and is easily soluble in glycerides and organic solvents but insoluble in water.
- BHA is fairly stable during typical fatty food processing and storage.
- It is seen as having a good carry-through effect as a result. BHA may, however, be lost in part during deep fat frying because it is volatile at high temperatures.
- BHT is a white, crystalline substance that has been butylated to hydroxy toluene. Additionally, it is insoluble in water and soluble in glycerides.It retains some of its carryover effect but loses some of it due to volatilization at high temperatures. Compared to BHA, BHT is less effective as an antioxidant.
- Propyl gallate is the n-propyl ester of gallic acid, or 3,4,5-trihydroxy benzoic acid. The powder ranges from white to light grey. It is significantly water soluble and poorly soluble in oil. Due to its heat liability, it has relatively low carry-through properties, especially in the alkaline conditions seen in baked goods, despite having very excellent antioxidant capabilities.
- In order to improve storage stability and carry-through protection, propyl gallate is used in conjunction with other antioxidants like Butylated Hydroxyanisole (BHA) **and** Tertiary Butylhydroquinone (TBHQ)
- It is a white to light tan crystalline solid known for enhancing the stability of fats and oils during storage. It is only slightly soluble in fats and oils and barely soluble in water. Unlike many other phenolic antioxidants, it does not form colored complexes with dietary metal ions such as iron. TBHQ provides excellent protection to fried foods during transport.

Uses of Phenolic Antioxidants:

As mentioned earlier, antioxidants are among the most widely used food additives. They are incorporated into a variety of products such as vegetable oils, meat products, confectionery and chewing gum, breakfast cereals, and baked goods. Although their use in fruit and vegetable products is relatively limited, they still hold significant economic importance due to their role in preserving quality and extending shelf life.

- Fruit nuts like walnuts, almonds, and cashew nuts are some of them, along with citrus oils and dehydrated potato goods like powder, flakes, and granules.
- All of the phenolic antioxidants mentioned above, with the exception of BHT, have been restrictedly allowed under PFA. Lecithin and ascorbyl palmitate are also acceptable for use in some food products.

6.12 ANTI CAKING AGENTS

- Anti-caking agents are anhydrous substances that are added sparingly to dry foods to keep the product dry and free-flowing and stop the particles from sticking together.
- Anti-caking chemicals work by absorbing extra moisture or by covering particles with a water-repellent coating.
- Dry soup, cake, and biscuit mixes would clump and chunk without anti-caking ingredients, hot chocolate and cappuccino vending machines would not work, and premixes for manufacturing would be more challenging to utilise.
- Baking powder, table salt, chocolate, milk and cream powders, flour-based mixes, and blended coffee beverages are just a few examples of products that frequently contain anti-caking ingredients. Anti-caking compounds are used during manufacture to help avoid bridging during the packing process, which can lower production rates.Powders can bridge or form an arch above the outlet of a container like a silo, hopper, or mixing vessel when particles interlock or link together.
- One of the most powerful anti-caking substances is silica, sometimes referred to as silicon dioxide. The most prevalent mineral in the earth's crust is silica, which is obtained from naturally occurring quartz. Additionally, it occurs naturally in water and plants. Silica adheres to food particles in powdered foods and prevents clumping. Additionally, silica is absorbed for dl-tocopheryl acetate and pantothenyl alcohol in tableted meals, used as a carrier and a defoamer, and used as a stabiliser in the brewing of beer.
- Another popular anti-caking ingredient, tricalcium phosphate (abbreviated as TCP), is used primarily to stop powered food from caking and lumping as well as to increase fluidity. It is frequently present in instant powders, table salt, spices, powdered milk, non-dairy creamer, and powdered drink mixes. Tricalcium phosphate, which is the calcium salt of phosphoric acid, is also used to raise the calcium content of food, primarily dairy substitutes.
- Several of the compounds with dual uses include:
- Additionally serving as a humectant, sweetener, and texturizer is mannitol (E421).
- Alpha (E460b) and microcrystalline (E460a) cellulose (E460a) are bulking, stabilising, and binding agents.
- Rice husk powder and maize starch are two alternatives to anti-caking agent additives that are available in various markets.One study, for instance, found that adding powdered rice to salt during manufacture as an anti-caking agent at a concentration of 1% might replace other popular anti-caking food additives used in the production of table salt.

- Anti-caking agents benefit businesses other than food, primarily the cosmetic and detergent industries.
- Indeed, it is projected that the great adaptability of anti-agents like silicon and tricalcium phosphate would further reinforce the expanding demand from a variety of sectors.

6.13 PROTECTIVE GASES

- In particular, packaging in a protective atmosphere is a technology that makes it simple to change the composition of the gases that are present in the packages during the packaging process. For instance, it does this by increasing nitrogen, an inert gas, and carbon dioxide, a bacteriostatic gas, to reduce the rate at which food naturally deteriorates due to the presence of oxygen. The gases utilised in this range are all strictly approved as food additives and naturally occur in our air. By adjusting the ratios of these gases in packaging, their properties can be employed to extend shelf life.
- The two main gases utilised are nitrogen and carbon dioxide, while oxygen is also used to package red meat and some varieties of fish. For better food preservation in packaging, gases such as oxygen, carbon dioxide, argon, and dioxide are employed. One of the biggest problems facing the food business has always been the desire from consumers for the preservation of food goods using natural methods. AliSOL is an efficient, effective solution to this demand.

Packaging in a protected environment enables:

- reduce or prevent the use of those chemical compounds used to reduce the main processes of natural deterioration of the product;
- increase the shelf life of fresh goods, even doubling it compared to packing in air;
- Improve production efficiency and the effectiveness of food product distribution.
- Avoid the crushing caused by vacuum packaging to preserve the original appearance of packed food.

6.14 LETS SUM UP

This unit provides information about food additives and preservatives used in food products to increase the shelf life. Food additives like acids, buffer systems and salts, chelating agents, antimicrobial agents, sweeteners, stabilizers and thickeners, fat replacers, firming texturizers, appearance control and clarifying agents, Flavor enhancers, aroma substances, sugar substitutes, sweeteners, antioxidants, Anti caking agents, protective gases are described in detailed.

6.15 CHECK YOUR PROGRESS

1. Define food additives.

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2. Define food stabilizers

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3. Write about artificial sweeteners

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4. Define fat replacers

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5. Write in brief about antimicrobial agents.

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6. Write in brief about flavor enhancers

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7. Define ant caking agents

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8. Write in brief about

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BLOCK-III

FOOD BORNE DISEASES, INDICATORS OF FOOD SAFETY, HACCP SYSTEM AND ROLE OF MICROBES

INTRODUCTION

Food safety is a crucial aspect of public health and nutrition. Contamination of food with harmful microorganisms, toxins, or parasites can lead to serious illnesses, economic losses, and reduced consumer confidence. This block provides an understanding of food-borne diseases, microbiological indicators of food safety, preventive systems like HACCP (Hazard Analysis and Critical Control Points), and the beneficial role of microbes in fermentation and biotechnology. Together, these units aim to equip learners with the knowledge to identify, control, and prevent microbiological hazards in food systems.

Unit 7: This unit discusses major bacterial and viral diseases transmitted through contaminated food and water. It explains the sources, symptoms, and prevention of infections caused by *Salmonella*, *Staphylococcus aureus*, *E. coli*, *Clostridium botulinum*, and viruses such as *Hepatitis A* and *Norovirus*. It also highlights parasitic infections (*Giardia*, *Taenia*, *Toxoplasma*) and introduces mycotoxins, toxic compounds produced by molds. The focus is on understanding routes of contamination and effective control measures to ensure food safety.

Unit 8: This unit outlines the microbiological standards and criteria used to assess food safety and quality. It explains the role of indicator organisms such as *Coliforms*, *E. coli*, and *Enterococci* in determining the sanitary quality of food and water. Methods of microbial testing, result interpretation, and their significance in maintaining food quality assurance are discussed. The unit emphasizes how such criteria guide producers and regulators in ensuring food meets safety standards.

Unit 9: This unit introduces the HACCP system, a systematic method for identifying and controlling hazards throughout food production. It describes the seven principles of HACCP, its implementation process, and its role in preventing microbial, chemical, and physical hazards. It also covers Good Manufacturing Practices (GMPs) and Good Hygiene Practices (GHPs) as essential prerequisites. The unit highlights HACCP's global importance as a preventive food safety approach from production to consumption.

Unit 10: This unit focuses on the beneficial role of microorganisms in food production, especially in fermentation and biotechnology. It explains how bacteria, yeasts, and molds are used to produce foods such as yogurt, cheese, bread, pickles, and soy products. The concept of genetically modified (GM) foods is also introduced, describing how microbial biotechnology enhances nutritional value, shelf life, and resistance to spoilage. The unit also discusses safety aspects of using microbes in modern food processing.

UNIT-VII FOOD BORNE DISEASES

7.1 INTRODUCTION

This unit will introduce you to various food borne diseases. It will give you a detailed overview of different bacteria, viruses, parasites and fungi responsible for food borne diseases. The unit gives you an understanding about concept of food poisoning and helps you to distinguish between food infection and food intoxication. The unit will also explain the about the organism involved, symptoms, contamination sources and foods related to various food illness. The unit will also cover the different types of mycotoxins produced by fungi growth in foods. The methods of prevention of food illness are also explained in detail.

Objectives

Learning this unit will make you:

- understand the concept of food poisoning
- differentiate between food infection and food intoxication
- discuss the different bacteria, viruses and parasites-based food borne illness.
- explain the symptoms and contamination sources of various food illness
- describe the different types of mycotoxins produced by fungi in foods
- discuss the methods of prevention of food illness

7.2 FOOD BORNE DISEASES

Food borne diseases are illnesses caused by consuming contaminated food or beverages. These diseases can be caused by a variety of microorganisms, including bacteria, viruses, parasites, and toxins produced by microorganisms (Table 1). These pathogens cause illness by infecting the body of a host. Infectious pathogens damage tissues and cells during growth in the host and sometimes release toxins that cause illness. Contaminated food can cause a range of symptoms, from mild to severe, and can affect individuals of all ages. Symptoms can include nausea, vomiting, diarrhea, abdominal pain, fever, and dehydration. In some cases, Food borne illnesses can lead to more serious health problems, such as kidney failure, meningitis, and even death.

Contamination of food can occur at various stages of the food chain, including during production, processing, transportation, storage, and preparation. Certain types of food are more prone to contamination than others, including raw or undercooked meat, poultry, fish, and shellfish, as well as raw fruits and vegetables that have not been properly washed. Preventing Food borne illnesses involves a combination of proper food handling and preparation, including washing hands and surfaces, cooking food to the proper temperature, and storing food at the appropriate temperature. Proper food safety practices can help to reduce the risk of contamination and ensure that food is safe to eat.

In addition to individual efforts, regulatory agencies play an important role in ensuring the safety of the food supply. Governments around the world have established food safety standards and regulations, and food producers and handlers are required to adhere to these standards to minimize the risk of Food borne illness. Regular monitoring and inspection of food production facilities and food products can help to identify potential sources of contamination and prevent outbreaks of Food borne illness. Food borne illness can be of two types:

- **Food borne infection** is caused by eating food contaminated with pathogens, including bacteria, parasites, and viruses. Once ingested, these pathogens infect the body, often in the intestinal tract causing infection and disease.
- **Food borne intoxication** is caused by ingesting food that contains pre-formed toxins produced by pathogens. Toxins may be produced by bacteria, mushrooms, moulds, or marine organisms. During intoxication, the pathogen may no longer be present in the food.

Table 1: List of Various organisms causing food borne illness

Bacteria	**Parasite**	**Virus**
E.coli O157:H7 *Bacillus cereus* *Campylobacter jejuni* *Clostridium botulinum* *Clostridium perfringens* *Listeria monocytogenes* *Salmonella* spp. *Shigella* spp. *Vibrio* spp. *Yersinia enterocolytica*	*Cryptosporidium* *Cyclospora* *Giardia* *Toxoplasma gondii* *Trichinella*	Hepatitis A virus (HAV) Norovirus Rotavirus

7.3 BACTERIAL DISEASES

7.3.1 Salmonellosis

Salmonellosis is a form of food infection that may result when foods containing Salmonella bacteria are consumed. The Salmonella family includes more than 2300 serotypes, but two types, *Salmonella enteritidis* and *Salmonella typhimurium* are the most common and account for half of the infections. Once eaten, the bacteria may continue to live and grow in the intestine, set up an infection and cause illness. The possibility and severity of the illness depends largely on the size of the dose, the resistance of the host and the specific strain of Salmonella causing the illness. Salmonella bacteria are spread through indirect or direct contact with the intestinal contents or excrement of animals, including humans. For example, they may be spread to food by hands that are not washed after using the toilet. They also may be spread to raw meat during processing so that it is contaminated when brought into the kitchen. Because of this, it is important to make sure hands and working surfaces are thoroughly washed after contact with raw meat, fish and poultry and before working with foods that require no further cooking. Salmonella bacteria grow at temperatures between 41 and 113 degrees F. They are readily destroyed by cooking to 160 F and do not grow at refrigerator or freezer temperatures. They do survive refrigeration and freezing, however, and will begin to grow again once warmed to room temperature.

Symptoms of salmonellosis include headache, diarrhea, abdominal pain, nausea, chills, fever and vomiting. These occur within 8 to 72 hours after eating contaminated food and may last four to seven days. Infants, young children, pregnant women, the elderly or people already ill have the least resistance to disease effects. Foods commonly involved include eggs or any egg-based food, salads (such as tuna, chicken, or potato), poultry, beef, pork, processed meats, meat pies, fish, cream desserts and fillings, sandwich fillings, raw sprouts, and milk products. These foods may be contaminated at any point where the food is handled or processed from the time of slaughter or harvest until it is eaten.

7.3.2 Campylobacteriosis

Campylobacteriosis or Campylobacter enteritis is caused by consuming food or water contaminated with the bacteria *Campylobacter jejuni. C. jejuni* commonly is found in the intestinal tracts of healthy animals (especially chickens) and in untreated surface water. Raw and inadequately cooked foods of animal origin and non-chlorinated water are the most common sources of human infection (e.g., raw milk, undercooked chicken, raw hamburger, and raw shellfish). The organism grows best in a reduced oxygen environment, is easily killed by heat (120 F), is inhibited by acid, salt and drying, and will not multiply at temperatures below 85 F. Diarrhea, nausea, abdominal cramps, muscle pain, headache and fever are common symptoms. Onset usually occurs two to ten days after eating contaminated food. Duration is two to seven days, but can be weeks with such complications as urinary tract infections and reactive arthritis. Meningitis, recurrent colitis, acute cholecystitis, and Guillain-Barre syndrome are rare complications. Deaths, also rare, have been reported. Preventive measures for Campylobacter infections include pasteurizing milk; avoiding post pasteurization contamination; cooking raw meat, poultry and fish; and preventing cross-contamination between raw and cooked or ready-to eat foods.

7.3.3 Listeriosis

Prior to the 1980s, listeriosis, the disease caused by *Listeria monocytogenes,* was primarily of veterinary concern, where it was associated with abortions and encephalitis in sheep and cattle. As a result of its wide distribution in the environment, its ability to survive for long periods under adverse conditions, and its ability to grow at refrigeration temperatures, Listeria has since become recognized as an important food borne pathogen. *L. monocytogenes* is frequently carried by humans and animals. The organism can grow in the pH range of 4.4 to 9.6. It is salt tolerant and relatively resistant to drying, but easily destroyed by heat. (It grows between 32 F and 113 F). Listeriosis primarily affects newborn infants, pregnant women, the elderly and those with compromised immune systems. In a healthy non-pregnant person, listeriosis may occur as a mild illness with fever, headaches, nausea and vomiting. Among pregnant women, intrauterine or cervical infections may result in spontaneous abortion or still birth. Infants born alive may develop meningitis. The mortality rate in diagnosed cases is 20 to 25 percent. The incubation period is a few days to several weeks. Recent cases have involved raw milk, soft cheeses made with raw milk, and raw or refrigerated ready-to-eat meat, poultry or fish products. Preventive measures for listeriosis include maintaining good sanitation, turning over refrigerated ready to-eat foods quickly, pasteurizing milk, avoiding post-pasteurization contamination, and cooking foods thoroughly.

7.3.4 Staphylococcal Intoxication

Staphylococcus bacteria are found on the skin and in the nose and throat of most people; people with colds and sinus infections are often carriers. Infected wounds, pimples, boils and acne are generally rich sources. Staphylococcus is also widespread in untreated water, raw milk and sewage. When Staphylococcus bacteria get into warm food and multiply, they produce a toxin or poison that causes illness. The toxin is not detectable by taste or smell. While the bacteria itself can be killed by temperatures of 120 F, its toxin is heat resistant; therefore, it is important to stop the staphylococcus organism from growing. Foods commonly involved in staphylococcal intoxication include protein foods such as ham, processed meats, tuna, chicken, sandwich fillings, cream fillings, potato and meat salads, custards, milk products and creamed potatoes. Foods that are handled frequently during preparation are prime targets for staphylococci contamination. Symptoms include abdominal cramps, vomiting, severe diarrhea and exhaustion. These usually appear within one to eight hours after eating staphylococcus infected food and last one or two days. The illness seldom is fatal. Keep food clean to prevent its contamination, keep it either hot (above 140 F) or cold (below 40 F) during serving time, and as quickly as possible refrigerate or freeze leftovers and foods to be served later.

7.3.5 *Clostridium perfringens* Food borne Illness

Clostridium perfringens belong to the same genus as the botulinum organism. However, the disease produced by *C. perfringens* is not as severe as botulism and few deaths have occurred. Spores are found in soil, nonpotable water, unprocessed foods and the intestinal tract of animals and humans. Meat and poultry are frequently contaminated with these spores from one or more sources during processing. Spores of some strains are so heat resistant that they survive boiling for four or more hours. Furthermore, cooking drives off oxygen kills competitive organisms and heat shocks the spores, all of which promote germination. Once the spores have germinated, a warm, moist, protein-rich environment with little or no oxygen is necessary for growth. If such conditions exist (i.e., holding meats at warm room temperature for several hours or cooling large pots of gravy or meat too slowly in the refrigerator), sufficient numbers of vegetative cells may be produced to cause illness. Foods commonly involved in *C. perfringens* illness include cooked, cooled, or reheated meats, poultry, stews, meat pies, casseroles, and gravies. Symptoms occur within eight to 24 hours after contaminated food is eaten. They include acute abdominal pain and diarrhea, nausea, vomiting and fever.

7.3.6 *E. coli* Hemorrhagic Colitis

Escherichia coli belongs to a family of microorganisms called coliforms. Many strains of *E. coli* live peacefully in the gut, helping keep the growth of more harmful microorganisms in check. However, one strain, *E. coli* O157:H7, causes a distinctive and sometimes deadly disease. Symptoms begin with non bloody diarrhea one to five days after eating contaminated food, and progress to bloody diarrhea, severe abdominal pain and moderate dehydration. In young children, hemolytic uremic syndrome (HUS) is a serious complication that can lead to renal failure and death. In adults, the complications sometimes lead to thrombocytopenic purpura (TPP), characterized by cerebral nervous system deterioration, seizures and strokes. Ground beef is the food most associated with E. *coli* O157:H7 outbreaks, but other foods also have been implicated. These include raw milk, unpasteurized apple juice and cider, dry-cured salami, sprouts, lettuce, spinach, and untreated water. Infected food handlers with the disease likely help spread the bacteria. Preventive strategies for *E. coli* infections include thorough washing and other measures to reduce the presence of the microorganism on raw food, thorough cooking of raw animal products, and avoiding recontamination of cooked meat with raw meat.

7.4 VIRAL DISEASES

Food borne infections caused by viruses are transmitted through the ingestion of food and water. They show high resistance to environmental factors, such as low pH (acidity) and heat. This makes them highly persistent so that they can remain infective for over a month in food and water. As they originate within the intestines of humans and animals, these viruses are predominantly spread through feces and other body fluids. The contamination of food stuff with pathogenic viruses is often caused by poor hygienic practices in the production line or contact of the food with animal waste or sewage.

Foods most commonly associated with food borne viruses include shellfish, which are harvested near human sewage outlets, undercooked meats as well as fruit and vegetables which are grown on animal waste fertilized grounds. Gastroenteritis and hepatitis are the most commonly reported syndromes of Food borne viruses. Although many different types of gastrointestinal viruses can be found in humans, gastroenteritis caused by the human norovirus and hepatitis A virus (HAV) are predominantly reported with Food borne viruses. Other viruses including enterovirus, sapovirus, rotavirus, astrovirus, adenovirus and Hepatitis E virus have also been associated with the transmissions through food and water.

Norovirus causes gastroenteritis leading to diarrhoea, vomiting, fever, headaches and abdominal pain. The disease is self-limiting, typically 12−48 hours up to 3 days for the majority of people, with a low infection dose of 10−100 virus particles. Prolonged virus shedding of up to 8 weeks may occur in asymptomatic people and immuno suppressed individuals. Headache and low-grade fever may occur and there is anecdotal evidence that there may be other diseases caused by Norovirus including infant necrotising enterocolitis. The primary route of transmission is person-to-person transmission through the faecal−oral and vomit-oral routes and indirectly through food (ready to eat including leafy vegetables and herbs, berries and foods handled after cooking), water and environment.

Rotaviruses are a group of non-enveloped viruses in the Reoviridae family, consisting of 8 species (named A−H). Rotavirus A is endemic worldwide, causing approximately 80% of rotavirus gastroenteritis in humans, particularly through waterborne infection, with rotavirus B and C also being human pathogens. Rotavirus gastroenteritis is a self-limiting, mild to severe disease characterized by vomiting, watery diarrhoea and low-grade fever. Symptoms usually start 1−2 days after infection with vomiting followed by 3−7 days of diarrhoea. Outbreaks caused by Group B rotavirus have been reported in the elderly and adults with Group C rotavirus being associated with sporadic cases of diarrhoea in children in many countries. Rotavirus gastroenteritis is a common and highly contagious form of viral gastroenteritis that affects primarily infants and young children. The virus is transmitted through contact with contaminated surfaces, objects, or food, as well as through person-to-person contact. Symptoms of rotavirus gastroenteritis typically include fever, vomiting, and diarrhea, which can be severe and can last for several days. Infants and young children may also experience dehydration, which can be serious and even life-threatening if not promptly treated. Rotavirus is the leading cause of severe diarrhea in children worldwide and is responsible for an estimated 200,000 deaths each year, mostly in developing countries. Treatment of rotavirus gastroenteritis typically involves managing symptoms and preventing dehydration. This may include giving oral rehydration solutions, which contain a balance of salts and sugars to replace fluids lost through diarrhea and vomiting. In severe cases, hospitalization may be necessary to provide intravenous fluids and electrolytes.

Another common food borne virus is Hepatitis A, which causes liver inflammation. Symptoms include fever, headache, nausea and vomiting, diarrhea, abdominal pain and jaundice. The virus is responsible for 50% of hepatitis cases and is often self-limiting which means the pathogen clears up or its host dies. However, Hepatitis A virus can rarely cause liver failure (requiring a liver transplant) or death. The potential of these viruses to spread across borders is immense due to the unrestricted travel conditions in many parts of the world. Due to the lack of appropriate detection methods to quantify the viral load present and the low levels of virus present in food, the risk of spreading remains.

7.5 FOOD BORNE PARASITES

Parasites are tiny organisms that live inside another organism. Some of the important foods borne parasites are discussed below:

7.5.1 *Cryptosporidium parvum*

Cryptosporidium parvum is a single-celled parasite that can infect the small intestine of humans and animals. It is spread through the consumption of contaminated food or water, or may be transmitted through contact with infected individuals or animals. Symptoms of cryptosporidiosis, the illness caused by Cryptosporidium infection, can include diarrhea, abdominal cramping, nausea, and vomiting. In healthy individuals, the illness usually resolves within a few days to a few weeks, but it can be more severe and long-lasting in people with weakened immune systems, such as those with HIV/AIDS.

Cryptosporidiosis can be diagnosed through laboratory tests that detect the parasite in stool samples. Treatment typically involves managing symptoms, such as dehydration, and allowing the body's immune system to fight off the infection. In severe cases, antiparasitic medications may be used. Preventing Cryptosporidium infection involves practicing good hygiene and avoiding contact with contaminated water and food sources. This can include washing hands thoroughly with soap and water, especially after using the restroom or changing diapers, avoiding drinking untreated water from rivers, lakes, or wells, and properly washing and cooking food. In areas where cryptosporidiosis is common, water should be boiled or treated with chlorine before consumption.

7.5.2 *Giardia intestinalis*

It is also known as *Giardia lamblia*, and is a single-celled parasite that can infect the small intestine of humans and animals. It is one of the most common parasites found in humans, and is transmitted through the intake of contaminated water or food, or through contact with infected individuals or animals. Symptoms of giardiasis, the illness caused by Giardia infection, can include diarrhea, abdominal pain, bloating, gas, and nausea. In some cases, individuals may also experience weight loss, fatigue, and dehydration.

Giardiasis can be diagnosed through laboratory tests that detect the parasite in stool samples. Treatment typically involves a course of antibiotics, which can help to alleviate symptoms and clear the infection. Preventing Giardia infection involves practicing good hygiene and avoiding contact with contaminated water and food sources. This can include washing hands thoroughly with soap and water, especially after using the restroom or changing diapers, avoiding drinking untreated water from rivers, lakes, or wells, and properly washing and cooking food. In areas where giardiasis is common, water should be boiled or treated with chlorine before consumption.

7.5.3 *Trichinella spiralis*

Trichinella spiralis is a parasitic roundworm that can infect humans and animals, such as pigs and wild game, that are commonly consumed by humans. The parasite is transmitted through the ingestion of undercooked or raw meat containing Trichinella larvae. Symptoms of trichinellosis, the illness caused by Trichinella infection, can include abdominal pain, diarrhea, fever, muscle pain, and swelling around the eyes. In severe cases, trichinellosis can lead to more serious complications, such as heart and lung problems.

Trichinellosis can be diagnosed through laboratory tests that detect the presence of antibodies to the parasite in blood samples. Treatment typically involves managing symptoms and using antiparasitic medications to eliminate the infection. Preventing Trichinella infection involves properly cooking meat to a safe temperature, which can kill Trichinella larvae. For pork, this means cooking it to an internal temperature of 145°F (63°C) and allowing it to rest for at least 3 minutes before carving or consuming. Foods that come into contact with contaminated water during growth or preparation can become contaminated with these parasites. Food handlers who are infected with these parasites can also contaminate foods if they do not thoroughly wash their hands after using the bathroom and before handling food. *Trichinella spiralis* is a type of roundworm parasite. People may be infected with this parasite by consuming raw or undercooked pork or wild game.

7.6 MYCOTOXINS

Mycotoxins have been defined as "fungal metabolites which when ingested, inhaled or absorbed through the skin, can cause disease or death in humans and domestic animals, including birds". Only a small number of such compounds are classified as mycotoxins; i.e., they have been demonstrated to cause illness in humans or domestic animals. Mycotoxin production occurs only as a result of fungal growth. However, if environmental conditions, particularly of temperature and water activity (aw), are conducive to fungal growth, toxin production may occur at any period during growing, harvesting, drying, or storage of food commodities. Mycotoxins may occur in processed foods, but are much less important than when they occur in commodities such as grains or nuts. Mycotoxins are typically chemically stable once formed, and persist in food even after the destruction of the fungi that produced them. Molecular structures of mycotoxins vary widely, so their effects on human and animal health also vary widely. They may be neurotoxins, teratogens, nephrotoxins, hepatotoxins, immunosuppressive agents or carcinogens. The most important mycotoxins are aflatoxins, ochratoxin A, fumonisins, deoxynivalenol and zearalenone.

7.6.1 Aflatoxins

Aflatoxins are a group of toxic and carcinogenic compounds produced by certain species of fungi, particularly *Aspergillus flavus* and *Aspergillus parasiticus*. These fungi can grow on a variety of crops, including peanuts, corn, cottonseed, and tree nuts, particularly in warm and humid conditions. Aflatoxins are classified into several different types, with aflatoxin B1 being the most toxic and carcinogenic. Aflatoxin B1 is also the most common type of aflatoxin found in contaminated food. Consumption of foods contaminated with aflatoxins can have serious health consequences, including liver damage, immune suppression, and an increased risk of liver cancer. Aflatoxins are particularly dangerous for young children and individuals with weakened immune systems.

Aflatoxins can be controlled through a variety of methods, including good agricultural practices, proper storage conditions, and food processing techniques such as sorting and dehulling. The use of fungicides can also help to prevent fungal growth and reduce the risk of aflatoxin contamination. Food manufacturers and regulatory agencies around the world have established strict limits on the allowable levels of aflatoxins in food products. These limits vary depending on the type of food and the country or region where it is produced and consumed.

7.6.2 Ochratoxin

Ochratoxin is a toxic and carcinogenic compound produced by several species of fungi, particularly *Aspergillus ochraceus* and *Penicillium verrucosum*. These fungi can grow on a variety of crops, including cereal grains, coffee, and grapes. Like aflatoxin, ochratoxin can be harmful to human health. Chronic exposure to ochratoxin has been linked to kidney damage and an increased risk of kidney cancer in humans. Ochratoxin has also been shown to be immunosuppressive and genotoxic, meaning that it can damage DNA and increase the risk of cancer. Ochratoxin contamination is a particular concern in certain food products, such as wine and coffee, where fungal growth is common. It can also occur in stored grains, particularly in warm and humid conditions.

Control of ochratoxin contamination is achieved through a combination of good agricultural practices, proper storage conditions, and food processing techniques. For example, reducing moisture levels during storage can help to prevent fungal growth and reduce the risk of ochratoxin contamination. In the wine industry, careful monitoring of grape quality and storage conditions can help to prevent fungal growth and reduce the risk of ochratoxin contamination in finished products. Regulatory agencies around the world have established limits on the allowable levels of ochratoxin in food products, with specific limits varying depending on the type of food and the country or region where it is produced and consumed.

7.6.3 Control of Mycotoxins

Control of mycotoxins involves a range of preventive measures aimed at reducing the growth of fungi that produce mycotoxins and minimizing the exposure of humans and animals to these toxins. Some of the key strategies for controlling mycotoxins include:

- Good agricultural practices like proper cultivation, harvesting, and storage of crops can reduce the risk of fungal growth and mycotoxin contamination. This includes techniques such as crop rotation, pest management, and the use of fungicides.
- Proper storage conditions: Storage conditions can significantly affect the growth of fungi and the production of mycotoxins. Proper storage conditions include maintaining low moisture levels, controlling temperature and humidity, and preventing insect infestations.
- Food processing techniques: Processing techniques such as sorting, cleaning, and dehulling can reduce the levels of mycotoxins in food products. For example, sorting can remove visibly contaminated grains, while dehulling can remove mycotoxin-contaminated outer layers of grains.
- Regulations and monitoring: Regulatory agencies around the world have established limits on the allowable levels of mycotoxins in food products. Regular monitoring of crops and food products can help to ensure compliance with these regulations and identify potential sources of mycotoxin contamination.
- Education and awareness: Educating farmers, food handlers, and consumers about the risks of mycotoxin contamination and the strategies for prevention can help to minimize exposure to these toxins.

Overall, the control of mycotoxins requires a comprehensive approach that involves prevention, monitoring, and regulatory oversight. By implementing these strategies, it is possible to reduce the risk of mycotoxin contamination and protect human and animal health.

7.7 PREVENTING FOOD BORNE ILLNESS

The following food handling practices have been identified as essential in preventing bacterial food borne illness:

- Keep packages of raw meat and poultry separate from other foods, particularly foods to be eaten without further cooking. Use plastic bags or other packaging to prevent raw juices from dripping on other foods or refrigerator surfaces.
- Buy products labeled “keep refrigerated” only if they are stored in a refrigerated case. Refrigerate promptly.
- Buy dated products before the label sell-by, use-by or pull-by date has expired.
- Wash hands (gloved or not) with soap and water for 20 seconds before preparing foods and after handling raw meat or poultry, touching animals etc.
- Rinse raw produce thoroughly under running tap water before eating.
- Scrub containers and utensils used in handling uncooked foods with hot, soapy water before using with ready-to-serve foods.
- Use separate cutting boards to help prevent contamination between raw and cooked foods.
- Serve cooked products on clean plates with clean utensils and clean hands.
- Keep hot foods hot (above 140 F) and cold foods cold (below 40 F).

- Refrigerate or freeze cooked leftovers in small, covered shallow containers (2 inches deep or less) within two hours after cooking. Leave airspace around containers to help ensure rapid, even cooling.
- Use cooked leftovers within 4 days. Don't taste leftovers to determine safety.
- If reheating leftovers, cover and reheat to appropriate temperature before serving.
- Discard outdated, unsafe or possibly unsafe leftovers in the garbage disposal or in tightly wrapped packages.

7.8 LET US SUM UP

In this unit we studied in detail about various food borne diseases. It gave you a detailed overview of different bacteria, viruses, parasites and fungi responsible for food borne diseases. The unit made you understanding about concept of food poisoning and helped you in differentiating between food infection and food intoxication. The unit explained about the organism involved, their symptoms, contamination sources and common foods related to various food illness. The unit also covered the different types of mycotoxins produced by fungi during its growth in foods. The various methods of prevention of food illness are also explained in detail.

7.9 CHECK YOUR PROGRESS

1. Differentiate between food infection and food intoxication.

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2. List some bacteria that cause food borne illness.

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3. Write a short note on salmonellosis.

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4. Explain food borne illness caused by virus.

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5. How can we prevent parasite infection in food?

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6. Define mycotoxins.

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7. Explain the measures involved in control of mycotoxins.

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Unit-VIII: INDICATORS OF FOOD SAFETY AND QUALITY: MICROBIOLOGICAL CRITERIA OF FOODS AND THEIR SIGNIFICANCE

Structure

8.1 INTRODUCTION

Unit 8 of this course will introduce you concept of food safety and food quality specifically in microbial terms. The unit will explain the relation of food quality with microbiological criteria. You will also understand the terms microbiological standard, specification, guidelines etc. The unit will also help you understand the difference between index and indicator microorganisms along with discussion of some indicator microorganisms in food. Further, methods for control of microbiological quality of foods will also be explained in this unit.

Objectives

After studying this unit, you will be able to:

- define food safety and food quality
- understand the relation of food quality with microbiological criteria
- comprehend the terms microbiological standard, specification, guidelines
- explain the difference between index and indicator microorganisms
- discuss some indicator microorganisms in food related to product quality
- describe control of microbiological quality of foods
- discuss the do’s and dont’s in a food plant to ensure the product quality

8.2 FOOD SAFETY AND FOOD QUALITY

Food plays a critical role in determining our health, nutritional status, and productivity. Therefore, it is imperative that the food we consume is free from plagiarism and safe for consumption. Unsafe food can lead to a large number of food borne diseases. You may have seen reports in the newspapers about health problems caused by contaminated or adulterated foods. Food-borne illness is a huge worldwide problem related to public health concern. Food-borne illness can not only result in mortality but can damage trade and tourism, lead to loss of earnings, unemployment and litigation and thus can impede economic growth, and therefore food safety and quality have gained worldwide significance. Ensuring the safety and quality of food is essential both at the household level and in large-scale food production, processing, and fresh food preparation and service, to prevent plagiarism and protect public health. Advancement in technology and processing, higher per capita incomes and better purchasing power as well as increased consumer demand have led to a variety of processed foods, food for health / functional foods being manufactured. Safety of such foods needs to be assessed. The quality of food stuff, raw as well as processed is of public health concern and must be addressed. In the past decade, safety challenges faced globally as well as in India have changed significantly and issues related to food quality and food safety have gained tremendous importance.

Food Safety

Food safety is an essential scientific discipline that involves proper handling, preparation, and storage of food to prevent food borne illnesses. This requires following specific routines to avoid severe health hazards, and food safety often overlaps with food defense to protect consumers from harm. In the food industry, food safety considerations include the origins of food, such as food labeling, food hygiene, food additives, and pesticide residues, as well as policies on biotechnology, guidelines for governmental import and export inspection, and certification systems for foods. On the other hand, market-to-consumer practices typically involve ensuring that food deemed safe in the market is delivered and prepared safely for the consumer. Food can transmit diseases from person to person, and it can also serve as a breeding ground for bacteria that cause food poisoning. Developed countries usually have complex standards for food preparation, while less developed countries often struggle with the availability of safe water, which is a critical issue for food safety.

Food Quality

Food quality refers to a set of characteristics that impact a product's desirability and value to consumers. This encompasses negative factors, such as spoilage, contamination, adulteration, and food safety hazards, as well as positive factors, such as color, flavor, and texture. It is therefore a holistic concept integrating factors such as nutritional traits, sensorial properties (colour, texture, shape, appearance, taste, flavour, odour), social considerations, safety. Safety is a preliminary attribute and precursor of quality. In order to ensure that foods are safe and of good quality, across the world various governments and international bodies have laid down food standards that manufacturers/suppliers are expected to adhere to.

8.3 QUALITY AND CRITERIA

The concept of quality in food can be defined as the "degree of excellence" of a product, which refers to how well it serves its intended purpose. In the context of food microbiology, quality encompasses three major characteristics:

- Safety: A food shall not contain levels of pathogens or toxins that can cause illness on its consumption.
- Shelf-life: A food should not contain microorganisms that would cause it to spoil or become unacceptable in oraganoleptic features within an unacceptable short period of time.
- Consistency: A food should maintain consistent quality in terms of safety and shelf-life over time.

These aspects of quality in food are essential to ensure that food products are safe for consumption, have an acceptable shelf-life, and are consistent in their quality characteristics. Consumers have a low tolerance for food products that exhibit significant variations in shelf-life and safety between batches. The principles and concepts for establishing microbiological criteria were developed by the International Commission on Microbiological Specifications for Foods (ICMSF) in the mid-1980s. These concepts have been used to develop recommendations for criteria for foods in international trade or for specific criteria for pathogens such as *Listeria monocytogenes*. They have also been the basis of the Codex Alimentarius Commission (CAC) document "*Principles for the Establishment and Application of Microbiological Criteria for Foods*". While CAC recognizes only the general category "microbiological criterion," other national, transnational, and international organizations, trade associations, and other stakeholders in the food chain often describe microbiological standards, guidelines, or specifications that can be differentiated as follows:

- *Microbiological standard* is a mandatory criterion included into a law or a regulatory ordinance.
- *Microbiological guideline* is an advisory criterion issued by either authorities, industry associations, or food manufacturers. Such guidelines are indicative of what can be expected for certain microbiological parameters when a food is manufactured according to best hygienic or manufacturing practices.
- *Microbiological specification* is an element of purchasing agreements between a buyer and a supplier of a raw material or a food product. Their use may be mandatory or advisory depending on the agreements between the two parties. Microbiological criteria have traditionally been developed around significant pathogens, relevant commensals and hygiene indicators as reflected in the ICMSF cases. They are widely used today to discriminate between acceptable and unacceptable lots of food products.

8.4 SAMPLING PLANS

Traditionally and historically, microbiological criteria have been established to determine whether a lot of product was suitable for commercial distribution and consumption. Acceptability of such a product was defined as the compliance to requirements for certain microorganisms (including parasites) and/or their toxins or metabolites. Requirements for microbiological criteria in food products are typically expressed as the absence or maximum allowable numbers or concentrations of specific parameters per unit(s) of mass, volume, area, or lot. These criteria are established to ensure that food products meet certain safety and quality standards and to prevent potential health hazards associated with microbial contamination. Microbiological criteria have been and are still widely used to make a decision upon analysis of a food for defined parameters. The analytical results obtained are compared to the established requirements and serve as a basis to decide whether a lot is acceptable or needs to be rejected.

The design of meaningful microbiological criteria used for lot acceptance is therefore a key step in the decision process. It must be considered that the development of such criteria is a complex process requiring the appropriate knowledge and information, resources, and efforts. They should therefore be developed only when there are clear benefits and justified need and when they are effective and practical in serving their purpose. Microbiological criteria, if deemed necessary and justified, are established to allow assessment of one or more of the objectives listed below:

- the safety of a specific food
- the hygienic quality of a food, in particular the adherence to good hygiene and manufacturing practices
- the suitability of a food or raw material for a particular usage such as its consumption or further processing
- the acceptability of a food or ingredient manufactured under unknown conditions

The foundation for the establishment of microbiological criteria was initially laid during joint consultations between the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). These organizations worked together to develop guidelines and principles for microbiological criteria in food safety to ensure the protection of public health and the maintenance of food quality standards. Since then, the outcome of these consultations has been continuously evolving with the input of the ICMSF, national governments, and academic researchers. These efforts resulted in the preparation of a document on the principles for the establishment of microbiological criteria issued by CAC.

The revision of this document was initiated in 2010 to take into account new developments in food safety management systems. To fulfill the purpose of the objectives, a microbiological criterion needs to be established for a specific food or a defined category of food showing similar characteristics, taking into account a number of elements including the following: the identification of recognized or potential health hazards associated with the food product, the microbiological quality of raw materials used in the food manufacturing process, the impact of processing on the microbiological status of the food, the possibility and potential consequences of microbial contamination during processing, subsequent handling, storage and use of the food product. These factors are taken into account to establish microbiological criteria that ensure the safety and quality of the food product.

A microbiological criterion is then established by translating the general principles given above into specific elements that should consist of the following:

- a description of the specific microorganism of concern and/or toxins/metabolites produced by it, where applicable, as well as the reason for the concern microbiological limits considered as appropriate to fulfill the objective the specific point(s) of the food chain at which the criterion would apply
- the number of analytical units that need to comply with the established limits
- a sampling plan defining the number of samples to be drawn for analysis
- the procedures to sample and handle the the size of the analytical unit as well as the appropriate analytical methods (qualitative or quantitative) capable of providing the adequate response with respect to the limits

- actions to be taken when the criterion or individual elements thereof are not met

8.5 INDEX AND INDICATOR MICROORGANISMS

Microorganisms need to be relevant for the specific food and its process and may encompass bacteria, viruses, yeasts, molds, algae, parasitic protozoa, and helminths as well as their toxins or metabolites. Microbiological criteria include normally relevant pathogens, hygiene indicators, and/or spoilage organisms. The current approach in the formatting of recently issued microbiological criteria is to make a clear distinction between food safety-related parameters and process hygiene indicators. The different elements constituting a microbiological criterion define the requirements and their stringency. Over time, two different terms have been used to describe and define such microorganisms, namely, index organisms and indicator organisms, and they are well established today.

Index microorganisms have been defined as microorganisms, groups of microorganisms, or microbial metabolites whose presence in numbers exceeding a specified limit would indicate the possible presence of pathogens showing a similar behavior and ecology. The intended role and purpose of index organisms are therefore to be used as a direct predictor of the presence of a specific pathogen. Such a prediction, however, is possible only if a statistically valid correlation has been established between the organism used as index and the "associated" specific pathogen.

Indicator microorganisms, on the other hand, have been defined as microorganisms, groups of microorganisms, or microbial metabolites whose presence in numbers exceeding specific limits would indicate a failure in the adherence to GHPs. The intended role and purpose of indicator organisms are thus to serve as an indirect predictor of the presence of a pathogen. It is therefore an indication of an increased risk related to a deviation of the implemented hygiene control measures. The direct testing for the specific pathogen cannot, however, be replaced by the sole testing for indicators.

Along with hygiene indicators, microorganisms, groups of microorganisms, or metabolites are also qualified as quality indicators. These quality indicators are usually related to physicochemical or organoleptical parameters and hence quality attributes of a food product. Their presence and growth can be associated with defective control measures leading to spoilage of food products. The use of indicators has been discussed by many authors, in particular in trying to define appropriate or ideal properties to fulfill their role both in raw materials, processing environment, and processing lines and in the end product. Methods for indicator organisms need to fulfill the same requirements as the one for pathogens, i.e., they need to be reliable and validated; in addition, they should be more rapid and less expensive. Quantitative results should show a correlation between indicator concentration and level of the pathogen.

8.6 INDICATORS OF PRODUCT QUALITY

Microbial product quality or shelf-life indicators are organisms and/or their metabolic products whose presence in given foods at certain levels may be used to assess existing quality or, better, to predict product shelf life. The indicator organisms should meet the following criteria:

1. They should be present and detectable in all foods whose quality (or lack thereof) is to be assessed.
2. Their growth and numbers should have a direct negative correlation with product quality. 3. They should be easily detected and enumerated and be clearly distinguishable from other organisms.

4. They should be enumerable in a short period of time, ideally within a working day.
5. Their growth should not be affected adversely by other components of the food microbiota.

In general, the most reliable indicators of product quality tend to be product specific. When a single organism is the cause of spoilage, its numbers can be monitored by selective culturing or by a method such as impedance with the use of an appropriate selective medium. The overall microbial quality of the products is a function of the number of organisms present, and shelf life can be increased by their control. In effect, microbial quality indicators are spoilage organisms whose increasing numbers result in loss of product quality. The products have confined biota, and decay is commonly the consequence of the development of a solitary organism. Microbial quality indicators are deterioration creatures whose expanding numbers bring about loss of product quality. Metabolic products might be utilized to evaluate and foresee microbial quality in certain products. Microbial indicators are mostly utilized to focus on examination of food safety and sanitation rather than quality. A food safety indicator should meet certain significant measures:

- Effectively and quickly perceivable.
- Effectively recognizable from other members of the food biota have a background marked by consistent relationship with the pathogen whose presence it is to indicate.
- Consistently be available when the pathogen of concern is available.
- An organism whose numbers ideally should connect with those of the pathogen of concern.
- Have development prerequisites and a development rate rising to those of the microorganism.
- Absent from food sources that are liberated from the pathogen with the exception of maybe at certain base numbers.

8.7 CONTROL OF MICROBIOLOGICAL QUALITY OF FOODS

The conventional method for managing microbiological quality at its source has typically based on a combination of a skilled workforce, thorough inspection of facilities, and supervision of operations, along with microbiological testing of not only finished products, but also ingredients, products in progress, equipment, environment, and personnel. This comprehensive approach aims to ensure that all aspects of the production process meet the required microbiological standards to maintain food safety and quality.

8.7.1 Training of Food Handlers

Food handlers should receive training on the fundamental concepts and requirements of food and personal hygiene, including specific aspects relevant to their particular food-processing operation. The level of training may vary depending on the type of operation and the job description of the employee, but at a minimum, induction training with regular updates or refresher courses should be provided. The training should aim to provide food handlers with an understanding of the basic principles of hygiene, the reasons for its importance, and practical ways to achieve it. Some key concepts that should be emphasized in such training include:

(1) Microbes are considered as the main reason of food spoilage and Food borne illness. They should have knowledge of the characteristics of the common food poisoning.

(2) Methods to prevent food poisoning by controlling microbial growth, their survival and cross

contamination.

(3) Standard requirements of personal hygiene of food handlers. These are mainly to prevent food contamination through the food handler. Microbes like *S. aureus*, *Salmonella* can be a part of skin microflora or they may carry these microbes from the outside premises to the plant, e.g. *Listeria, B. cereus*.

(4) Basic principles of food handling and food storage like importance and correct use of refrigerators and freezers, temperature monitoring, stock rotation etc.

(5) Proper cleaning and sanitation process and the need of the rigrous cleaning.

(6) Information about the common pests found in food plant premises and methods to be adopted for their elimination and control.

(7) Brief knowledge of the requirements of current food legislation in the country.

These aspects should be exaplained and informed with supplementary material related to the specific food being handled. Some important instructions of personal hygiene for food handlers are given below:

- Wash hands regularly, especially after using the washroom, before handling food or equipment, after handling raw foods, after touching hair, after eating, smoking, coughing or blowing the nose, and after handling waste food, garbage, or chemicals.
- Keep fingernails short and clean.
- Cover any cuts, spots, or boils with a waterproof dressing.
- Keep hair clean and covered to prevent hair/dandruff from entering food.
- Always wear clean protective clothing, including footwear, in food processing areas.
- Do not smoke, chew gum, tobacco, betel nut, fingernails, or anything else.
- Do not taste food.
- Do not spit, sneeze, or cough over food.
- Do not pick nose, ears, or any other body site.
- Do not wear jewelry when handling food.
- Do not wear protective clothing outside the production areas.

8.7.2 Facilities and Process

The environment where processing of food is done, plays a crucial role in determining product quality. The premises should be adequately sized for the intended scale of operation and located in areas that are free from issues such as pest infestations, objectionable odors, smoke, or dust. The site should be easily accessible by metalled roads and have reliable supplies of power and potable water suitable for the intended purpose. Proper attention should also be given to the provision of facilities for efficient disposal of processing wastes.

Buildings must be constructed soundly and maintained in good repair to protect raw materials, equipment, personnel, and products from contamination and prevent the entry of pests. The areas surrounding the plant should be well-maintained, with regular lawn cutting and a grass-free strip of gravel or tarmac around the buildings. Well-kept grounds not only enhance aesthetics but also aid in pest control, as features such as ponds may attract birds and insects and are therefore not advisable.

It is essential that the buildings provide a comfortable and pleasant working environment that promotes good hygienic practices. They should have adequate lighting, ventilation, and size to maintain appropriate separation between processes to prevent cross-contamination. Some process areas may require features such as temperature and relative humidity control, as well as positive pressure with filtered air, for the well-being of both personnel and products. In processing areas, floors should be made of durable, impervious, non-slip, washable materials, and free from cracks or crevices that could harbor contamination. Where applicable, floors should be gently sloped towards floor drains with trapped outlets. Internal walls should be smooth, impervious, easy to clean and disinfect, and light in color. The junction between floors and walls should be covered to facilitate cleaning.

Food processing facilities should have light-colored ceilings that are easy to clean and constructed to minimize condensation, mould growth, and flaking. Any pipework, light fittings, or other services should avoid creating difficult-to-clean recesses or overhead condensation. A false ceiling may be used to separate processing areas from overhead services in particularly sensitive areas. Light fittings should be covered to prevent food contamination in the event of a bulb or fluorescent tube shattering. Windows should have sloped sills and may be covered with well-maintained fly screens in some climates. All entrances to the plant should be protected by close-fitting, self-closing doors to prevent the ingress of birds and other pests. Air curtains may also be used to protect some work areas.

Toilets and changing facilities should be clean, comfortable, well-lit, and provide secure storage for employees' belongings. Toilets should not open directly onto food-processing areas and must be provided with hand-washing facilities supplied with hot water, soap, and hand-drying facilities. Ideally, taps and soap dispensers should be of the non-hand-operated type, and single-use disposable towels or an air blower should be provided for hand-drying. Hand washing facilities should also be available elsewhere in the plant wherever the process demands. The overall layout of the plant should ensure a smooth flow-through from raw materials reception and storage to product storage and dispatch. Areas may be designated as 'high risk' or 'low risk' depending on the sensitivity of the materials being handled and the processes used. High and low-risk areas of a production process should be physically separated, should use different sets of equipment and utensils, and workers should be prevented from passing from one area to the other without changing their protective clothing and washing their hands. The same rules governing access, behavior, and the wearing of protective clothing apply to management, visitors, and anyone requiring to visit the processing area.

8.7.3 Equipment

Equipment and its failures can be a potent source of product contamination. The design of hygienic food-processing equipment should aim to efficiently and economically perform the prescribed task while protecting the food from contamination. The basic principles of hygienic design, adapted from the Institute of Food Science and Technology (UK) publication 'Good Manufacturing Practice: A Guide to its Responsible Management', with slight modification, are as follows:

- All surfaces that come in contact with food should be inert to the food under conditions of use and must not release any substance that could migrate to or be absorbed by the food.
- All working surfaces in contact with food should be microbiologically cleanable, smooth, and non-porous to prevent particles from getting caught in small surface crevices, which could be difficult to dislodge and act as a potential source of contamination.

- All surfaces must be visible for inspection, or the equipment must be easily dismantled for inspection, or it must be demonstrated that routine cleaning procedures eliminate the possibility of contamination.
- Equipment surfaces in contact with food must be easily available for manual cleaning, or if clean-in-place (CIP) techniques, it should be demonstrated that the results achieved with CIP are equivalent to those obtained with manual cleaning.
- All internal surfaces should be designed in a way that the equipment is or self-draining without any dead spaces that can trap food and allow microbial growth.
- Equipment must be designed to protect the food from external contamination and should not self contaminate through leaking glands, lubricant drips or inappropriate modifications or adaptations.
- External surfaces of equipment should be designed to avoid the harboring of soils, microorganisms, or pests on equipment, floors, walls, and supports.
- Where ever appropriate, equipment should be fitted with devices that can monitor and record its performance, such as temperature/time, flow, pH, or weight.

8.7.4 Cleaning and Disinfection

In the course of its use, food processing equipment will inevitably become soiled with food residues, which can negatively impact its performance and potentially serve as a source of microbiological contamination. Therefore, proper and frequent cleaning of both premises and equipment is crucial to maintain hygiene in food processing operations. Cleaning should be considered an integral and essential part of the production process, rather than a rushed or superficial end-of-shift task.

It's important to note that visual cleanliness alone may not be sufficient, as surfaces that appear clean may still harbor viable microorganisms that can contaminate the food product. Therefore, cleaning operations in food processing serve two purposes: physical cleaning to remove visible soil from surfaces, which can protect microorganisms and serve as a source of nutrients, and microbiological cleaning, also known as sanitizing or disinfection, to reduce the numbers of adhering microorganisms to acceptable levels after physical cleaning.

A two-stage cleaning process is generally recommended for best results, although combined detergent/sanitizers may be used in cases of light soiling for simplicity. In a general cleaning/disinfecting procedure, gross debris should be removed first by brushing or scraping, possibly followed by a pre-rinse with clean, potable (drinking quality) water. This should be followed by a more thorough cleaning step that involves the application of a detergent solution. The composition of the detergent will depend on the nature of the soil to be removed, but it typically contains surfactants, which are compounds that have both polar (hydrophilic) and non polar (hydrophobic) portions. Surfactants help reduce the surface tension of the aqueous phase in the detergent, improving its penetrating and wetting ability, and contributing to other useful properties such as emulsification, dispersion, and suspension.

8.8 LET US SUM UP

This unit explained the concept of food safety and food quality. The unit also explained the relation of food quality with microbiological criteria. The terms microbiological standard, specification, guidelines etc were discussed in relation to food quality. The unit also helped you to understand the difference between index and indicator microorganisms as well as discussed, some important indicator microorganisms in food. Lastly, methods for control of microbiological quality of foods like training, equipment, facilities, cleaning etc. were also described.

8.9 CHECK YOUR PROGRESS

1. Define:

   (a) Food Safety

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   (b) Food Quality

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   (c) Microbiological guidelines

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   (d) Index microorganisms

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2. Write the full form of:

   (a) ICMSF

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   (b) CAC

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   (c) FAO

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(d) WHO

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3. What are indicator microorganisms?

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4. Write a short note on training of food handlers to maintain microbial quality of foods.

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5. How can equipments serve as the source of food contamination?

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Unit-IX THE HACCP SYSTEM AND FOOD SAFETY USED IN CONTROLLING MICROBIOLOGICAL HAZARDS

Structure

9.1 INTRODUCTION

This unit will acquaint you with concept of food safety and its concern for public health. It will introduce you to the principles of Food Safety Management System. The unit gives you an understanding about basics of GMP, GHP, HACCP and Codex Alimentarius. The unit will also cover the need of HACCP and terminology associated with HACCP. The seven principles of HACCP are explained in detail. The implementation of HACCP, benefits and Applications of HACCP are also discussed.

Objectives

After learning this unit, you will be able to:

- explain the concept of food safety
- define food hazards
- understand the importance of food safety management systems
- explain the principles of GMP and GHP
- understand the terminology of HACCP
- describe the principles of HACCP and its implementation
- explain the benefits and applications of HACCP

9.2 CONCEPT OF FOOD SAFETY

Food safety is a broad discipline that encompasses the handling, preparation, and storage of food in a manner that prevents Food borne illnesses. It involves a set of routines and practices that must be followed to avoid potential health hazards. Food safety often intersects with food defense, which aims to prevent harm to consumers. When considering practices from industry to market, food safety considerations include the origin of food, food labeling, food hygiene, food additives, pesticide residues, biotechnology policies, and governmental import/export inspection and certification systems for foods. When considering practices from market to consumer, the primary concern is that food should be safe in the market, and there is a focus on safe delivery and preparation of food for consumers.

The quality of food stuff, raw as well as processed is of public health concern and must be addressed. In the past decade, safety challenges faced globally as well as in India have changed significantly and issues related to food quality and food safety have gained tremendous importance. A number of factors are responsible for this:

- With swift changes in lifestyle patterns and eating habits, large numbers of people are not eating homemade food. In commercial settings, foods are prepared in bulk handled by many persons, thus there are more chances of food getting contaminated. Further, food items are prepared many hours in advance, and may spoil if not stored appropriately.
- There are many processed and packaged foods in the market and safety of these foods is very important.
- Spices and condiments, oilseeds were processed at home in former times and purity of these were not a concern. In today's world, pre- packaged individual spices, condiments, spice powders and mixes are in demand, especially in cities and metros. Quality of even raw food stuff besides processed foods is of public health concern and must be addressed.
- Logistics governing transport of bulk food is complex and there is a long gap between processing and consumption. Thus, risk assessment and safety management during mass production and mass distribution is critical.
- Microbial adaptations, antibiotic resistance, altered human susceptibility and international traveling have all contributed to increasing incidence of food-borne microbial diseases. Nearly half of all known food-borne pathogens have been discovered during the past 25-30 years. There

are still many food borne illnesses of unknown etiology. This is an issue of global public health concern and there is a need to detect, identify and recognise emerging pathogens and establish active surveillance networks, nationally and internationally.

- India being a signatory of non-tariff agreement of World Trade Organisation (WTO), has provided huge opportunities to world markets and access to all countries to participate in international trade. In this scenario, it has become essential for every country to protect the safety and quality of foods and also ensure that imported foods are of good quality and safe to eat. Efficient food standards and control systems are necessary to safeguard domestic food production and facilitate international trade with other countries.All food manufacturers are required to meet the given standards of quality and safety, and need to have their products regularly tested.

Owing to the above factors, there is a growing concern for safe, wholesome and nutritious foods in a highly dynamic food business environment, which in turn has greatly expanded the scope and has increased career opportunities in this sector.

9.3 FOOD HAZARDS

Food safety means assurance that food is acceptable for human consumption according to its intended use. An understanding of food safety is improved by defining two other concepts i.e. toxicity and hazard. Toxicity refers to the inherent ability of a substance to cause harm or injury under any circumstances. Hazard, on the other hand, is the relative likelihood that harm or injury will occur when a substance is not used as directed, in the prescribed amount or manner. Hazards can be physical, chemical and biological causing harmful / adverse effects on the health of consumers.

Physical hazard is any physical material not normally found in food, which causes illness or injury and includes wood, stones, parts of pests, hair etc.

Chemical hazards are substances that can be added to food, either intentionally or unintentionally, and pose a risk to health and safety. This category of hazards includes pesticides, chemical residues, toxic metals, polychlorinated biphenyls, preservatives, food colours and other additives.

Biological hazards are living organisms and include microbiological organisms. Those micro-organisms which are associated with food and cause diseases are termed food-borne pathogens. There are two types of food-borne diseases from microbial pathogens; infections and poisoning.

Among the various hazards, biological hazards pose a significant threat of food-borne illnesses. Despite all the efforts in the field of food safety, food-borne pathogens are still a critical concern with new pathogens that continue to emerge.

9.3.1 SOURCES OF HAZARDS

The emergence of pathogens is influenced by various factors, including the human host, animal hosts and their interactions with humans, the characteristics of the pathogen itself, as well as environmental factors such as food production, processing, handling, and storage practices (Fig 1).

Raw Materials

Raw materials are the primary source of contamination. Failure to follow basic quality assurance procedures (identification and labelling, Storage conditions, Handling requirements, Preparation and processing and Isolation of unsuitable raw materials) on raw materials may lead to food products that are unsafe for consumption.

Processing Steps

Uncontrolled processing operations can lead to hazardous conditions. Failure to maintain processing conditions such as temperature or time delay in processing, incorrect formulations and procedures and following unauthorized processing techniques may all result in contamination or microbial growth. Poor cleaning practices may leave excess cleaning chemical residues on plant and equipments.

Machinery

Unclean and unhygienic equipment can easily promote the growth of microorganisms. Preventive maintenance of machinery is an important aspect in a safety management program. If safety requirements are ignored, the layout of the machinery and equipment can be a potential hazard. The machinery should be examined at intervals to ensure a safe operation.

Handling of Food

Personal hygiene is extremely important in any food serving establishment. If adequate precautions are not taken, food handlers can transmit pathogenic bacteria. Personal articles such as jewellery can get mixed with foods during preparation.

Environmental Conditions

Hazards due to environmental conditions may affect raw materials, processing and machinery. Pollution of water and soil can have alarming results through the food chain. Environmental contamination may also be due to foreign matter, chemicals such as sprays and contaminants in water.

Fig. 1: Sources of Food Hazards

9.4 FOOD SAFETY MANAGEMENT SYSTEMS

Over the years, issues related to food safety and quality has gone beyond just the avoidance of food-borne pathogens, chemical toxicants and other hazards. A food hazard can be caused in food at any stage of the food chain, thus, proper monitoring and control is required throughout the food chain. Food safety and quality can be ensured through Good Manufacturing Practices (GMP), Good Handling Practices (GHP) and Hazard Analysis Critical Control Points (HACCP).

9.4.1 Good Manufacturing Practices (GMP)

Good Manufacturing Practices (GMPs) lie at the Heart of Quality. GMPs are also known as current Good Manufacturing Practices (cGMPs), are a series of manufacturing and administrative procedures aimed at ensuring that products are consistently made to meet specifications and customer expectations. In relation to food, GMP results in safe and quality food. The three elements of GMP are Food Safety, Good Practice and Quality. A preventive approach to the safety of foods is more effective than testing or inspection of processed foods at the final stage. GMP assures food safety through vigilant measures at the source product design and process control. It enables to minimise or eliminate contamination and false labelling, thereby protecting the consumer from being misled and helping in purchasing products that are not harmful. GMP is a good business tool that helps to refine compliance and performance by the manufacturers/producers.

9.4.2 Good Handling Practices (GHP)

These are a set of guidelines and practices that are designed to ensure that food is produced, processed, handled, and stored in a safe and hygienic manner to prevent contamination and maintain food safety. GHP includes practices such as personal hygiene of food handlers, proper cleaning and sanitization of food contact surfaces, safe storage and handling of raw and cooked foods, and proper temperature control during food production and storage. GHP is an important aspect of food safety management systems and is often implemented in food production facilities, restaurants, and other food handling establishments to minimize the risk of Food borne illnesses and ensure the safety of consumers.

9.4.3 Hazard Analysis Critical Control Point (HACCP)

HACCP is a means of providing assurance about safety of food. HACCP is an approach to food manufacture and storage in which raw materials and each individual step in a specific process are considered in detail and evaluated for its potential to contribute to the development of pathogenic micro organisms or other food hazards. It involves identifying potential hazards, assessing their likelihood of occurrence at various stages in the food chain, including raw material procurement, manufacturing, distribution, and product usage, and defining effective measures to control and mitigate these hazards.

9.5 CODEX ALIMENTARIUS

The Codex Alimentarius is a collection of internationally adopted food standards, codes of practice, guidelines and recommendations. They have been created for the purpose of protecting the health of consumers and ensuring fair practices in the food trade. Recognizing the importance of HACCP to food control, the twentieth session of the Codex Alimentarius Commission, held in Geneva, Switzerland from 28 June to 7 July 1993, where *Guidelines for the implementation of the Hazard Analysis Critical Control Point* (*HACCP*) *system* were adopted. The Codex General Principles of Food Hygiene lay a firm foundation for ensuring food hygiene. They follow the food chain from primary production through the consumer, highlighting the key hygiene controls at each stage and recommending a HACCP approach wherever possible to enhance food safety. These controls are internationally recognized as essential to ensure the safety and suitability of food for human consumption and international trade.

Codex Alimentarius is literally translated from Latin, a **"food code"**. It comprises a series of general and specific food safety standards that have been formulated with the objective of protecting consumer health and ensuring fair practices in the food trade. Food put on the market for local consumption or export must be safe to eat and of good quality. In addition, food should not carry disease-causing organisms that could harm animals or plants in importing countries. Codex Alimentarius is run by the Codex Alimentarius Commission, which is an intergovernmental body where all member countries have a vote. Various specialist committees are responsible for drafting standards, which are then adopted by the Codex Commission.

9.6 WHY IMPLEMENT HACCP?

It is a proactive perspective to ensure food safety. End product inspection and testing, although important, is time consuming, expensive and detects the problems only after they occur. In contrast, HACCP (Hazard Analysis and Critical Control Points) empowers the detection of hazards at any stage of processing or manufacturing, allowing for timely corrective action to ensure the production of safe and high-quality end products. It enables producers, processors, distributors, and exporters to optimize resource utilization in a cost-effective manner to ensure food safety.FSSA, 2006 places primary responsibility for safe food with producers and suppliers through HACCP, GMP, GHP. These guidelines are important for consumer protection, international food trade as well as to attain good quality products, consistently.

9.7 TERMINOLOGY

The following terms are used in discussion of HACCP that must be clearly understood to effectively develop and implement a plan.

1. ***Acceptable Level*** means that the presence of hazard which does not pose the likelihood of causing an unacceptable health risk.
2. ***Control point***refers to a point within a food system where a loss of control would not result in an unacceptable health risk.
3. ***Critical control*** point is defined in the food Code, as a point at which loss of control may result in an unacceptable health risk.
4. ***Critical Limit*** is the highest or lowest value that a physical, biological, or chemical parameter must be regulated to at a critical control point in order to reduce the possibility of the identified food safety hazard from occurring.
5. ***Deviation*** refers to the inability to meet the essential critical limit at a critical control point.
6. ***HACCP plan*** as defined in the Food Code, means a written document that delineates the formal procedures for following the HACCP principles developed by The National Advisory Committee on Microbiological Criteria in Foods.
7. ***Hazard,*** as defined in the Food Code, means a biological, chemical, or physical property that may cause an unacceptable consumer health risk.

8. ***Monitoring*** refers to a planned series of observations or measurements of critical limits that are aimed at generating a precise record and verifying that the critical limit maintains product safety. "Continuous monitoring" refers to an unbroken record of data.
9. ***Preventive*** measure means an action to exclude, destroy, eliminate, or reduce a hazard and prevent recontamination through effective means.
10. ***Risk*** means an estimate of the likely occurrence of a hazard.
11. ***Sensitive ingredient*** means any ingredient historically associated with a known microbiological hazard that causes of contributes to production of a potentially hazardous food as defined in the Food Code.
12. ***Verification*** means methods, procedures, and tests used to determine if the HACCP system in use in compliance with the HACCP plan.

9.8 THE HAZARD ANALYSIS AND CRITICAL CONTROL POINT (HACCP) CONCEPT

In the modern food industry, the Hazard Analysis Critical Control Point (HACCP) concept has largely replaced the traditional approach based on Good Manufacturing Practice. HACCP is a rule-based approach that leverages our knowledge of food microbiology to control microbiological quality more efficiently. While it can also be applied to physical and chemical factors affecting food safety or acceptability, this text will focus on microbiological hazards. It is important to note that HACCP is primarily a preventative approach to quality assurance, and it can be used to design quality and develop novel products during their development. The concept was initially developed as part of the United States space program by the Pillsbury Company, the National Aeronautics and Space Administration (NASA), and the US Army Natick Laboratories. They used it to apply the same zero defects philosophy to food for astronauts as to other items of their equipment. HACCP is based on an engineering system called the Failure Modes Analysis Scheme, which examines a result and all its components with questioning at each step "What can go wrong?"

In 1973, the US Food and Drug Administration approved HACCP for the examination of low-acid canned food. Since then, it has been increasingly applied to all aspects of food manufacture, food processing, and food service, at all scales of operation from large industrial concerns to cottage industries and even domestic food preparation. The meaning of the terms "hazard" and "threat" in the HACCP system differs from their general everyday usage as synonyms. In HACCP, a hazard is a source of risk defined as the unacceptable contamination, development, or survival of a microorganism that can compromise safety or shelf-life, and/or the unacceptable creation or persistence in food of microbial metabolites affecting safety or shelf-life. Individual hazards can be evaluated in terms of their severity and threat, with a hazard to food safety being more severe than one to shelf-life. For instance, botulism is a more severe hazard than Staphylococcus aureus food poisoning. Risk is an estimate of the likely incidence of a hazard, and although C. botulinum is a more severe hazard, epidemiological evidence indicates that the risk it poses is typically very low.

Best HACCP can be planned and conducted only by involvement of a multidisciplinary team including microbiologist, process supervisor, engineer, and quality assurance manager, where all can contribute their expertise and knowledge to solve the problem. Input from production personnel will also ensure compliance with the plan by those who will have to execute it. Specific microbial hazards should be identified in the study's terms of reference to allow the team to define specific controls. The selection of hazards to be considered will entirely depend on whether there is epidemiological evidence linking a particular microorganism with the food being processed. In the absence of any such confirmation, product's physical and chemical characteristics and its end use by the customer must offer the basis for selection.

Scope of HACCP

- Aggressive competition required organization to reduce costs while maintaining quality.
- Increasing consumer awareness and legal liability to produce safe food
- Changes in processed technology, increased automation, complex packaging solutions, new ingredients and improved formulations.
- Greater emphasis on sensory evaluations and complex distribution networks leading to reduce delivery times.

9.9 PRINCIPLES OF HACCP

In past few years national and international bodies have agreed on a definition based on seven important principles of a HACCP system:

(1) Conduct a hazard analysis.

(2) Determine the Critical Control Points (CCPs).

(3) Establish critical limits.

(4) Establish a system to monitor control of the CCP.

(5) Establish corrective action to be taken when monitoring indicates that a particular CCP is not under control.

(6) Establish procedures to verify that the HACCP system is working effectively.

(7) Establish documentation concerning all procedures and records

To apply these principles in practice it is necessary to go through a series of steps outlined in Table 1.

Table 1: Steps in the application of HACCP

Sl. No.	**Steps Required**	**HACCP Principle Involved**
1	Assemble the HACCP team	
2	Describe the product	
3	Identify intended use	
4	Construct flow diagram	
5	On-site confirmation of flow diagram	
6	List all potential hazards	Principle 1

Sl. No.	Steps Required	HACCP Principle Involved
7	Conduct a hazard analysis	
8	Determine control measures	
9	Determine CCPs	Principle 2
10	Establish critical limit for each CCP	Principle 3
11	Establish a monitoring system for each CCP	Principle 4
12	Establish corrective action for deviations that may occur	Principle 5
13	Estabish verification procedures	Principle 6
14	Estabish documentation of procedures and records	Principle 7

9.9.1 Hazard Analysis

Hazard Analysis is a crucial step in the HACCP system and involves identifying potential hazards in the food production process that could pose a threat to consumer safety. It is important to approach this step systematically by examining all raw materials, ingredients, and processing steps, as well as potential sources of contamination throughout packaging, distribution, and storage.

The hazard analysis must identify raw materials and ingredients that may contain harmful microorganisms or toxic metabolites, as well as the likelihood of these hazards occurring and the severity of their adverse health effects. The potential for contamination at different stages in processing must also be evaluated, as well as the physical and chemical characteristics of intermediates and products that could promote microbial growth or the production of toxic metabolites.

To effectively control these hazards, measures such as lethal or bacteriostatic process steps must be identified. The expertise of a food microbiologist is crucial in this step to distinguish between microbiologically sensitive raw materials and ingredients, and to provide quantitative tools such as predictive models to estimate potential microbial growth or survival at each step.

9.9.2 Identification of Critical Control Points (CCPs)

Identification of Critical Control Points (CCPs) is a crucial step in HACCP, which involves identifying specific points in the production process where potential hazards can be controlled or eliminated to ensure the safety of the final product. CCPs are the points in the production process where a failure to control a hazard would result in an unacceptable risk to the consumer or product.

To identify CCPs, a hazard analysis is conducted to identify potential hazards and the steps in the production process where they are likely to occur. Then, the decision tree is used to determine which of these steps should be designated as CCPs. Decision trees are designed to help identify CCPs by asking a series of questions, such as whether a control measure exists at a particular step or if a hazard can be eliminated or reduced to an acceptable level. Once the CCPs have been identified, specific control measures are implemented to ensure that the hazards are effectively controlled or eliminated. The control measures may include process modifications, such as temperature or pH adjustments, the use of microbial inhibitors, or changes to equipment design, employee hygiene, or sanitation practices.

The effective identification of CCPs requires a thorough understanding of the production process, the hazards that may be present, and the control measures that can be implemented to ensure the safety of the final product. The process should be reviewed regularly to ensure that CCPs remain effective and that new hazards are identified and controlled as necessary.

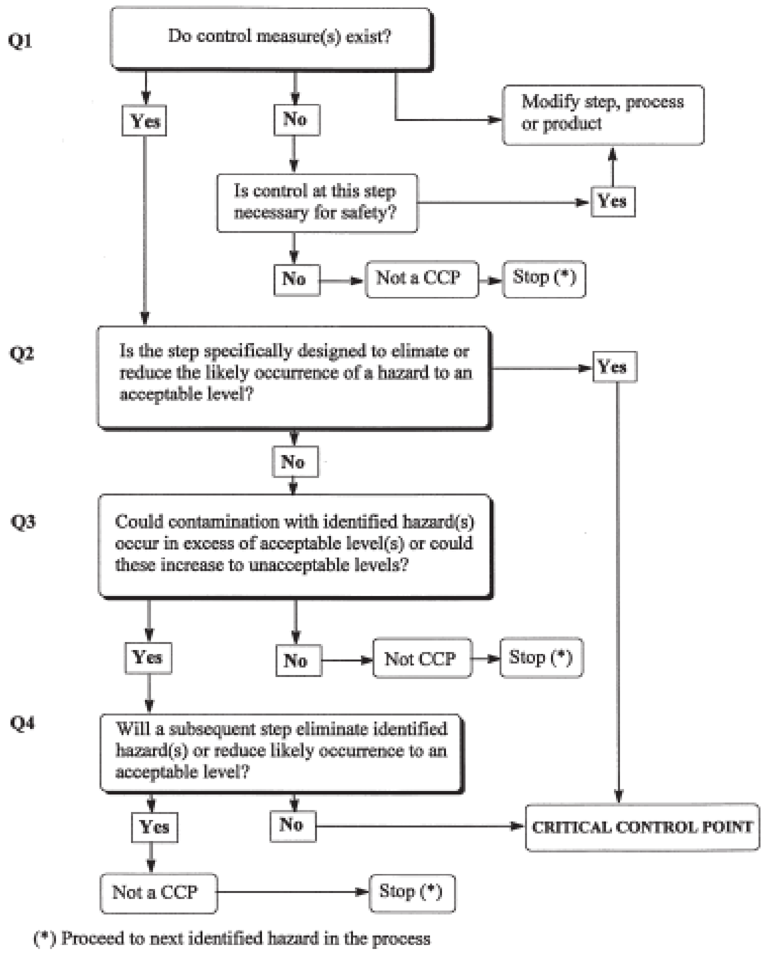

Fig 2: Decision tree

9.9.3 Establishment of CCP Critical Limits

After identifying the CCPs, the next step is to establish critical limits for each CCP. Critical limits are specific parameters or values that must be met to ensure that the hazard is controlled at the CCP. These limits can be based on regulatory requirements, scientific studies, industry standards, or other sources of information. Critical limits can be physical, chemical, or biological parameters, such as temperature, pH, water activity, microbial count, and so on. For example, the critical limit for a cooking CCP may be a minimum temperature of 165°F for a specific time period, while the critical limit for a storage CCP may be a maximum temperature of 40°F.

It is important to establish critical limits that are measurable and can be monitored in real-time or near-real-time. This enables the identification of deviations from the critical limits and the implementation of corrective actions to prevent the production of unsafe food products. The establishment of critical limits must be based on scientific and technical information, and involve the collaboration of food safety experts, microbiologists, process engineers, and other relevant personnel. The process of establishing critical limits should also take into account the characteristics of the product, the production process, and the intended use of the product.

Once the critical limits have been established, they must be documented and communicated to all relevant personnel involved in the production process. They should also be regularly reviewed and updated to ensure that they are still appropriate and effective in controlling the identified hazards.

9.9.4 Monitoring Procedures for CCPs

After establishing the criteria for critical limits for each CCP, it is important to implement monitoring procedures to ensure that these limits are consistently met. Monitoring involves the measurement or observation of a parameter or CCP at a specific point in the process, which enables the identification of any deviations from the critical limits.

Monitoring procedures should be designed to provide a timely indication of process control and the ability to detect any loss of control before a hazard occurs. These procedures should include the use of appropriate equipment, sampling plans, and analytical methods. For example, a monitoring procedure for a CCP that involves cooking temperatures may include the use of a temperature probe to measure the internal temperature of the food product during the cooking process.

The frequency of monitoring should be established based on the level of risk associated with the CCP and the likelihood of deviations occurring. Monitoring should be frequent enough to detect any loss of control before a hazard occurs. However, overly frequent monitoring can be resource-intensive and may not add significant value. Monitoring records should be kept to document the results of monitoring activities, including the date and time of the measurement or observation, the individual responsible for the monitoring, and the results obtained. These records are important for verifying that the process is under control and for identifying any trends or patterns that may indicate a need for corrective action.

Monitoring procedures for CCPs are critical to ensure that critical limits are consistently met and that deviations from these limits are detected in a timely manner. The frequency of monitoring should be established based on the level of risk associated with the CCP, and monitoring records should be kept to document the results of monitoring activities.

9.9.5 Protocols for CCP Deviations

These are the procedures that should be followed when a deviation from the established critical limit occurs at a CCP. Deviations can occur due to equipment failure, human error, or any other unforeseen circumstances. The protocols should be designed to ensure that the deviation is identified, documented, and resolved in a timely and appropriate manner to prevent any potential harm to the consumer or product. It is important to have protocols in place for CCP deviations to ensure that any potential hazards are identified and addressed promptly.

9.9.6 Verification

Verification is the process of evaluating the effectiveness of the HACCP system in controlling hazards and ensuring the safety of the food product. This involves a series of activities to ensure that the system is working as intended and that the identified hazards are being effectively controlled.

It includes activities such as reviewing and updating the HACCP plan, reviewing and evaluating monitoring data and records, conducting internal audits, and verifying that corrective actions have been taken when necessary. The goal of verification is to ensure that the HACCP system is operating effectively and that any deficiencies or weaknesses are identified and corrected. The verification process should be conducted by trained individuals who are independent of the HACCP team and who have the necessary expertise to evaluate the effectiveness of the system. There are several different methods that can be used to verify the HACCP system, including: Internal Audits, Product Testing, equipment Calibration, Process Verification, Record Review and Challenge Testing.

Verification should be conducted on an ongoing basis to ensure that the HACCP system remains effective over time. Any issues or problems that are identified during the verification process should be addressed immediately to prevent the production of unsafe food. The results of verification should be documented, and any necessary corrective actions should be taken to ensure that the HACCP system remains effective.

9.9.7 Record Keeping

Record keeping is an essential part of a HACCP plan. The purpose of record keeping is to provide a written history of the HACCP system, including all activities and procedures that have been followed, and any deviations that have occurred. This information is used to demonstrate that the system is being properly implemented and that the products are safe for consumption. Records should be kept for all CCPs, and should include information such as monitoring results, corrective actions taken, and verification activities. Records should also include information about product specifications, supplier information, and any other relevant information that pertains to the safety of the product.

The type of records that should be kept will vary depending on the nature of the product and the specific hazards that are being controlled. For example, records might include temperature logs for refrigeration units, pH readings for acidified products, or microbial test results for ready-to-eat products. The HACCP team should establish procedures for maintaining and reviewing records, and for ensuring that all necessary information is recorded accurately and completely. Records should be kept in a secure location and should be easily accessible for review by regulatory agencies or auditors.

Effective record keeping is critical for the success of a HACCP plan. It provides a means of tracking the performance of the system, identifying areas for improvement, and demonstrating compliance with regulatory requirements.

9.10 BENEFITS OF IMPLEMENTING THE HACCP SYSTEM

Application of an effective HACCP system has clear benefits for consumers, industry as well as regulatory bodies.

Benefits for Consumers

- Lower risk of food borne illnesses
- Greater awareness of food safety
- Greater confidence in food supply
- Better quality of life through health and socioeconomic benefits

Benefits for Industry

- Greater consumer confidence on product
- Minimizes legal and insurance costs
- Increases market access

- Lower wastage, fewer no recalls, minimum or no reprocessing, and corrective action
- A consistent product
- Enhanced staff commitment to food safety
- Lower business risk

Benefits for Regulatory Bodies

- Improved health among the community
- More efficient food control
- Lower public health costs
- Trade promotion
- Greater confidence of the community in the food supply

9.11 APPLICATIONS OF HACCP

While the application of HACCP to all segments and sectors of the food chain is possible, it is assumed that all sectors should be operating according to good manufacturing practices (GMPs) and the Codex General Principles of Food Hygiene. The ability of an industry segment or sector to support or implement the HACCP system depends on the degree of its adherence to these practices. The successful application of HACCP requires the full commitment and involvement of management and the workforce. It requires a multidisciplinary approach which should include as appropriate, expertise in agronomy, veterinary health, microbiology, public health, food technology, environmental health, chemistry, engineering, etc. according to the particular situation. The application of the HACCP system is compatible with the implementation of TQM systems such as the ISO 9000 series. However, HACCP is the system of choice in the management of food safety within such systems.

9.12 LET US SUM UP

In this unit we got acquainted with concept of food safety and food hazards. It introduced you to the principles of Food Safety Management System. The unit gave you an understanding about principles of GMP, GHP, HACCP and Codex Alimentarius. The unit also explained the need of HACCP and terminology associated with HACCP. The seven principles of HACCP were discussed in detail. The implementation of HACCP, benefits and applications of HACCP were also described.

9.13 CHECK YOUR PROGRESS

1. Define:

   (a) Food Hazard

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   ....
   ....

   (b) Toxicity

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(c) Chemical hazards

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(d) Critical limit

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(e) Decision tree

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2. Write full form of :

(a) GMP

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(b) GHP

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..............(c) HACCP

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(d) FSSA

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..............(e) CCP

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3. What are the principles of HACCP?

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4. Explain the step identification of critical control points in HACCP.

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5. What are the benefits of implementing the HACCP?

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Unit-X ROLE OF MICROBES IN FERMENTED FOODS AND GENETICALLY MODIFIED FOODS

Structure

10.1 INTRODUCTION

This unit will give you an understanding of fermentation process and history of fermentation. It will introduce you to different types of fermented foods and the microorganisms involved in preparation of these foods. The unit gives you an understanding about fermented milks, meat, fish, vegetables, vinegar, cheese as well as probiotics. The unit will also introduce you to the concept of GM foods. The advantages and risks associated with use of GM foods are also discussed.

Objectives

After studying this unit, you will be able to:

- understand basics of fermentation
- explain history of fermentation
- identify the microorganisms involved in preparation of fermented foods

- understand the term probiotics
- explain the concept of GM foods
- understand the advantages and limitations of use of GM foods

10.2 FERMENTATION

Fermentation is the process that is used in converting sugar to gases or to alcohol. It is also used to refer to the growth of microorganisms with the aim of producing a specific chemical product.

Fermentation is a metabolic process that converts sugar to acids, gases, or alcohol. It occurs in yeast and bacteria, and also in oxygen-starved muscle cells, as in the case of lactic acid fermentation. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium, often with the goal of producing a specific chemical product. The science of fermentation is known as zymology. Fermentation takes place when the electron transport chain is unusable (often due to lack of a final electron receptor, such as oxygen). In this case it becomes the cell's primary means of ATP (energy) production. It turns NADH and pyruvate produced in glycolysis into NAD+ and an organic molecule (which varies depending on the type of fermentation). In the presence of O2, NADH and pyruvate are used to generate ATP in respiration. This is called oxidative phosphorylation, and it generates much more ATP than glycolysis alone. For that reason, cells generally benefit from avoiding fermentation when oxygen is available, the exception being obligate anaerobes which cannot tolerate oxygen. Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to aerobic respiration, as long as sugars are readily available for consumption (a phenomenon known as the Crabtree effect). The antibiotic activity of hops also inhibits aerobic metabolism in yeast. Fermentation reacts NADH with an endogenous, organic electron acceptor. Usually this is pyruvate formed from the sugar during the glycolysis step. During fermentation, pyruvate is metabolized to various compounds through several processes:

- ethanol fermentation, aka alcoholic fermentation, is the production of ethanol and carbon dioxide
- lactic acid fermentation refers to two means of producing lactic acid:
  - homolactic fermentation is the production of lactic acid exclusively
  - Heterolactic fermentation is the production of lactic acid as well as other acids and alcohols.

Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, carbon dioxide, and hydrogen gas (H2). However, more exotic compounds can be produced by fermentation, such as butyric acid and acetone. Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of carbon dioxide. Fermentation occurs in mammalian muscle during periods of intense exercise where oxygen supply becomes limited, resulting in the creation of lactic acid.

10.3 HISTORY OF FERMENTATION

Natural fermentation precedes human history. Since ancient times, humans have exploited the fermentation process. The earliest evidence of an alcoholic drink, made from fruit, rice, and honey, dates from 7000 to 6600 BC, in the Neolithic Chinese village of Jiahu, and winemaking dates from 6000 BC, in Georgia, in the Caucasus area. Seven-thousand-year-old jars containing the remains of wine, now on display at the University of Pennsylvania, were excavated in the Zagros Mountains in Iran. There is strong evidence that people were fermenting alcoholic drinks in Babylon c. 3000 BC, ancient Egypt c. 3150 BC, pre-Hispanic Mexico c. 2000 BC, and Sudanc. 1500 BC. Fermented foods have a religious significance in Judaism and Christianity. The Baltic god Rugutis was worshiped as the agent of fermentation. The first solid evidence of the living nature of yeast appeared between 1837 and 1838 when three publications independently concluded as a result of microscopic investigations that yeast is a living organism that reproduces by budding. The focus on yeasts in early studies on fermentation in Europe was likely due to their importance in making basic foods such as wine, beer, and bread. However, researchers soon discovered the presence of bacteria as well. The term "bacteria" was first used in English during the late 1840s, but it did not become commonly used until the 1870s, particularly in relation to the emerging germ theory of disease. Louis Pasteur (1822–1895), during the 1850s and 1860s, showed that fermentation is initiated by living organisms in a series of investigations. In 1857, Pasteur showed that lactic acid fermentation is caused by living organisms. In 1860, he conducted an experiment that demonstrated how bacteria cause souring in milk, which was previously thought to be a chemical change. This discovery led to the process of pasteurization, which involves heating milk to kill harmful bacteria and extend its shelf life.

Pasteur also investigated the role of microorganisms in food spoilage and correctly showed that specific types of microorganisms cause specific types of fermentations and specific end-products. He defined fermentation as "Life without air," although this definition was later proven to be incorrect. Nonetheless, his work paved the way for a better understanding of the role of microorganisms in food processing, preservation, and spoilage.

Although showing fermentation to be the result of the action of living microorganisms was a breakthrough, it did not explain the basic nature of the fermentation process, or prove that it is caused by the microorganisms that appear to be always present. In 1897, Eduard Buechner, a German chemist, successfully extracted a juice from yeast that was able to ferment a sugar solution, even though the yeast cells were dead. This discovery marked the birth of biochemistry and showed that fermentation is caused by enzymes produced by microorganisms. Buechner's findings also led to the term "enzyme" being applied to all ferments. In 1907, Buechner was awarded the Nobel Prize in chemistry for his work.

Since then, advances in microbiology and fermentation technology have continued to develop. In the late 1970s, it was discovered that microorganisms could be mutated with physical and chemical treatments to be higher-yielding, faster-growing, and more tolerant of less oxygen, and able to use a more concentrated medium. Strain selection and hybridization were also developed, which have had a significant impact on modern food fermentations. Other approaches to advancing the fermentation industry have been done by companies such as BioTork, a biotechnology company that naturally evolves microorganisms to improve fermentation processes. This approach differs from the more popular genetic modification, which has become the current industry standard.

10.4 FERMENTED FOODS

10.4.1 Fermented milks

Fermented milk is a dairy product that has undergone a fermentation process, which converts lactose into lactic acid. This result in a tangy taste, thicker consistency, and longer shelf life compared to regular milk. The fermentation process of fermented milks involves the conversion of lactose, the main sugar in milk, into lactic acid by lactic acid bacteria (LAB) or other microorganisms. This process gives fermented milks their characteristic tangy taste and creamy texture. The fermentation process can be carried out either naturally or through the addition of starter cultures. Natural fermentation occurs when raw milk is left at room temperature, allowing naturally present bacteria to ferment the milk. This process, however, can lead to inconsistent results and potential safety issues. The use of starter cultures, which contain specific strains of LAB, is the preferred method for fermenting milk in a controlled and consistent manner. The most commonly used LAB for milk fermentation is *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, which are often used together as a starter culture.

The fermentation process usually takes place at a temperature of around 40-45°C for several hours, depending on the desired texture and flavor of the final product. During fermentation, the LAB metabolizes the lactose in the milk and produce lactic acid, which lowers the pH of the milk, causing it to thicken and form a gel-like texture. After fermentation, the fermented milk can be further processed through homogenization, flavoring, and sweetening to produce various types of fermented milk products, such as yogurt, kefir, and buttermilk. There are several types of fermented milk products that are popular around the world, including:

- Yogurt: It is the most well-known fermented milk product. It is made by adding a starter culture of Lactobacillus bulgaricus and Streptococcus thermophilus to heated milk. The culture ferments the lactose in the milk, producing lactic acid and thickening the milk. Yogurt can be consumed plain or flavored with fruit, honey, or other sweeteners.
- Kefir: It is a fermented milk drink that originated in the Caucasus Mountains. It is made by adding kefir grains, a combination of yeast and bacteria cultures, to milk. The grains ferment the lactose in the milk, producing lactic acid and carbon dioxide, which gives kefir its characteristic fizzy texture. Kefir can be consumed plain or flavored with fruit or honey.
- Buttermilk: Buttermilk is a fermented milk product that is made by adding lactic acid bacteria to skim milk. It has a tangy taste and a thicker consistency than regular milk. It is commonly used in baking to add moisture and acidity to recipes.
- Labneh: Labneh is a Middle Eastern yogurt cheese that is made by straining yogurt to remove the whey. The resulting product is thick and creamy, similar in texture to cream cheese. It is often flavored with herbs, spices, or olive oil and used as a spread or dip.
- Ayran: It is a Turkish fermented yogurt drink that is made by mixing yogurt with water and salt. It has a thin consistency and a salty, tangy taste. It is often consumed as a refreshing drink in hot weather and is sometimes flavored with mint or other herbs.
- Filmjölk: Filmjölk is a Swedish fermented milk product that is made by adding a starter culture of Lactococcus lactis and Leuconostoc mesenteroides to milk. It has a tangy taste and a thinner consistency than yogurt. It is often consumed plain or with fruit and granola for breakfast.
- Amasi: It is a South African fermented milk product that is made by adding a starter culture of lactic acid bacteria to milk. It has a sour taste and a thick, creamy texture. It is often consumed as a snack or used in cooking.

Consumption of these fermented milks provide a variety of health benefits, such as improved digestion, strengthened immune system, and better absorption of nutrients. the health benefits of fermented milk products are likely due to a combination of probiotic bacteria and other bioactive compounds.

10.4.2 Cheese

Cheese is a dairy product made from milk that has undergone a process of coagulation and separation of the curd from the whey. One of the key processes in cheese production is fermentation, which is carried out by microorganisms such as bacteria and fungi that are added to the milk or naturally present in the milk. Fermentation plays several important roles in cheese production, including:

- Acidification: The primary function of fermentation in cheese production is to acidify the milk. During fermentation, the microorganisms convert lactose, the primary sugar in milk, into lactic acid. This lowers the pH of the milk, which helps to coagulate the proteins and separate the curd from the whey.
- Flavor development: Fermentation also plays a critical role in developing the flavor and aroma of cheese. Different microorganisms produce different compounds that contribute to the unique flavor and aroma of each type of cheese. For example, some bacteria produce diacetyl, which gives buttery and nutty flavors, while others produce compounds that contribute to the sharp and tangy flavor of cheddar cheese.
- Texture and structure: Fermentation also helps to develop the texture and structure of cheese. The acid produced during fermentation can cause the proteins in the milk to denature and coagulate, forming a solid curd. The curd can then be cut and pressed to remove excess whey, resulting in a firmer cheese.

There are two main types of fermentation used in cheese production: lactic acid fermentation and ripening or maturation fermentation. Lactic acid fermentation is the first step in cheese production and involves adding lactic acid bacteria to the milk. The bacteria consume lactose and produce lactic acid, which lowers the pH of the milk and causes the proteins to coagulate. This results in the formation of a soft curd, which is then cut and separated from the whey.

Ripening or maturation fermentation, on the other hand, is a slower process that occurs after the cheese has been formed. During ripening, a variety of microorganisms such as bacteria, yeasts, and molds are allowed to grow on the surface of the cheese. These microorganisms break down the proteins and fats in the cheese, producing a variety of flavor compounds and contributing to the unique texture and structure of the cheese. There are many different types of fermented cheese, each with its own unique flavor, aroma, and texture. Some examples of fermented cheese include:

- Blue cheese: It is made by adding the mold Penicillium roqueforti to the milk during the cheese-making process. The mold grows throughout the cheese, forming blue-green veins and producing a sharp, tangy flavor.
- Brie: Brie is a soft cheese that is made by allowing the mold Penicillium camemberti to grow on the surface of the cheese. This mold forms a white rind around the cheese and produces a mild, creamy flavor.
- Cheddar: Cheddar is a hard cheese that is aged for several months or even years. During the aging process, bacteria break down the proteins and fats in the cheese, producing a sharp, tangy flavor.
- Gouda: It is a semi-hard cheese that is aged for several months. During the aging process, bacteria break down the proteins and fats in the cheese, producing a nutty, caramel-like flavor.
- Feta: Feta is a crumbly cheese that is made by allowing bacteria to grow on the surface of the cheese. This produces a tangy, salty flavor and a crumbly texture.

Fermentation is a critical process in cheese production that contributes to the flavor, texture, and structure of the final product. By carefully controlling the types of microorganisms used and the conditions in which they grow, cheesemakers can create a wide variety of unique and delicious cheeses.

10.4.3 Alcoholic Beverages

An alcoholic beverage is a drink that contains ethanol, which is commonly known as alcohol. The consumption of beer has been a cultural practice for over 8,000 years. Drinking beer and other alcoholic beverages in local bars or pubs is a cultural norm in Germany, Ireland, the United Kingdom, and many other European countries. Non-alcoholic beverages, on the other hand, typically contain less than 0.5% alcohol by volume, such as low-alcohol beer, non-alcoholic wine, and apple cider.

Wine fermentation is a crucial step in winemaking that involves the conversion of grape juice into alcohol and carbon dioxide by microorganisms, specifically yeast. The process starts with the harvesting of ripe grapes, which are then crushed and destemmed to remove stems and leaves. Afterward, yeast is added to the grape juice to initiate fermentation, during which yeast consumes the sugars in the juice and converts them into alcohol and carbon dioxide. The duration of fermentation and the type of yeast used greatly influence the flavor, aroma, and alcohol content of the wine. After fermentation is complete, the wine is aged and clarified before being bottled and consumed. The quality of the grapes, the fermentation process, and the aging process all play a significant role in the final product of the wine.

Preparation of beer involves the conversion of sugars present in malted grains into alcohol and carbon dioxide by yeast. The process starts with mashing, where malted grains are mixed with hot water to extract sugars and create wort, a sweet liquid. The wort is then boiled with hops to add flavor and bitterness, and the liquid is cooled and transferred to a fermentation vessel. Yeast is added to the vessel, and fermentation begins as the yeast consumes the sugars in the wort and converts them into alcohol and carbon dioxide. The process can take several days to complete, depending on the type of beer and the desired alcohol content. After fermentation, the beer is transferred to a conditioning vessel, where it undergoes a maturation process to develop its flavor and aroma. The beer is then filtered, carbonated, and bottled or kegged for consumption. The fermentation process plays a significant role in determining the final flavor and alcohol content of the beer, making it a crucial step in beer production.

Cider fermentation is a natural process that involves converting apple juice into alcoholic cider through the action of yeast. The process begins with the harvesting of ripe apples, which are then washed, crushed, and pressed to extract their juice. The juice is strained to remove any pulp or debris before adding yeast to initiate fermentation. The type of yeast used greatly influences the flavor, aroma, and alcohol content of the final product. The fermentation process can take anywhere from one to three months, depending on the desired alcohol content and the temperature and humidity of the fermentation environment. During fermentation, yeast consumes the natural sugars present in the juice and produces alcohol and carbon dioxide as byproducts. After fermentation is complete, the cider is transferred to a storage vessel, where it is aged and conditioned to improve its flavor and clarity. Cider fermentation is a vital step in producing high-quality cider, and proper fermentation techniques are essential to achieving the desired taste and alcohol content.

There are numerous other types of alcoholic drinks besides wine, beer, and cider, including spirits which are distilled alcoholic drinks made from fermented grains, fruits, or vegetables eg. Whiskey, vodka, gin, rum, and tequila; Liqueurs are sweetened alcoholic drinks that are often flavored with fruits, herbs, spices, or nuts eg. Amaretto, Bailey's Irish Cream, and Grand Marnier; Mead is a fermented alcoholic beverage made from honey, water, and yeast. It is one of the oldest alcoholic beverages in the world and has been enjoyed for thousands of years; Sake is a traditional Japanese alcoholic beverage made from fermented rice with a distinct flavor and aroma and is often enjoyed with

Japanese cuisine; Brandy is a distilled spirit made from fermented fruit juice or wine often aged in oak barrels to develop its flavor and aroma.

10.4.4 Fermented Vegetables

Most horticultural products can be preserved by lactic acid fermentation. In the West, the most important commercial vegetables are cabbage, cucumbers and olives, although smaller amounts of others such as carrots, cauliflower, celery, okra, onions, sweet and hot peppers, and green tomatoes are also fermented. In Korea, fermented vegetables known as kimchi are an almost ubiquitous accompaniment to meals. More than 65 different types of kimchi have been identified on the basis of differences in raw materials and processing. Cabbages and radishes are the main substrates but garlic, peppers, onions and ginger are often also used. Surveys have shown its importance in the Korean diet, variously reporting kimchi to comprise 12.5% of the total daily food intake or a daily adult consumption of 50–100 g in summer increasing to 150–200 g in winter. Sauerkraut production is thought to have been brought to Europe from China by the Tartars. Like a number of other traditional fermentations, the commercial process is technologically simple, but involves some interesting and complex chemistry and microbiology. Usually where sauerkraut is produced commercially special cabbage cultivars are grown. These tend to have higher solids content than normal and so minimize production of liquid waste during processing.

10.4.5 Fermented Meat

Fermented meat products are defined as meats that are deliberately inoculated during processing to ensure sufficient control of microbial activity to alter the product's characteristics. If fresh meat is not preserved or cured in some manner, it spoils rapidly owing to the growth of indigenous gram-negative bacteria and subsequent putrefaction resulting from their metabolic activities. Although some manufacturers still depend upon naturally occurring microflora to ferment meat, most use starter cultures consisting of a single species or multiple species combinations of lactic acid bacteria (LAB) and/or staphylococci that have been selected for metabolic activities especially suited for fermentation in meat ecosystems. Understanding the technological, microbiological, and biochemical processes that occur during meat, poultry, and fish fermentation is essential for ensuring safe, palatable products. Dry and semidry sausages represent the largest category of fermented meat products, with many presentday processing practices having their origin in the Mediterranean region. Traditionally, dry sausages acquired their particular sensory characteristics from exposure to salt; indigenous gram-positive microorganisms such as LAB, coagulase-negative cocci, including staphylococci and kocuria (*Micrococcus* spp. that were mostly used for fermented meat were reclassified as *Kocuria* spp. in 1995), and yeasts residing on the meat; and the rapid drying conditions that exist in the warm, dry Mediterranean climate. These products were heavily seasoned and stuffed into sausage casings that excluded air, which favored the growth of certain gram-positive bacteria such as LAB. Typically, they were not smoked and preserved after fermentation while the accumulation of lactic acid, other organic acids, carbon dioxide, and alcohols served as the preservatives. The name "sausage" was derived from the Latin term salsus, meaning "salted." Sausage processing practices later spread to northern Europe, and by the middle Ages, hundreds of varieties of dry and semidry sausages were manufactured across the continent.

10.4.6 Fermented Fish

Fermented fish products include a variety of fish sauces, fish pastes, and fish-vegetable blends that have been salted, packed whole in layers, or ground into small particles and then fermented in their own "pickle." These products are eaten as a proteinaceous staple or condiment in Southeast Asia but are consumed as a condiment in northern Europe. Fish fermentation involves minimal bacterial conversion of carbohydrates to lactic acid but entails extensive tissue degradation by proteolytic and lipolytic enzymes derived from viscera and muscle tissues. Low-molecular-weight compounds from fish tissue degradation are the primary contributors to aroma and flavor characteristics of sauces. Indigenous microorganisms, however, do contribute to aroma and flavor but are limited to species tolerant of high salt concentrations (10 to 20%) in the curing brine. Partial tissue hydrolysis is responsible for the unique textural attributes of pastes and fish-vegetable blends.

10.4.7 Vinegar

Vinegar is the product of a two-stage fermentation process. In the first stage, yeasts convert sugars into ethanol anaerobically, while in the second ethanol is oxidized to acetic (ethanoic) acid aerobically by bacteria of the genera Acetobacter and Gluconobacter. This second process is a common mechanism of spoilage in alcoholic beverages and the discovery of vinegar was doubtless due to the observation that this product of spoilage could be put to some good use as a flavouring and preservative. The name vinegar is in fact derived from the French *vin aigre* for 'sour wine' and even today the most popular types of vinegar in a region usually reflect the local alcoholic beverage; for example, malt vinegar in the UK, wine vinegar in France, and rice vinegar in Japan. In vinegar brewing, the alcoholic substrate, known as vinegar stock, is produced using the same or very similar processes to those used in alcoholic beverage production. In the production of malt vinegar for example, hops are not used and the wort is not boiled so the activity of starch-degrading enzymes continues into the fermentation. Acetification, the oxidation of ethanol to acetic acid is performed by members of the genera Acetobacter and Gluconobacter. These are Gram negative, catalase-positive, oxidase-negative, strictly aerobic bacteria. Acetobacter spp. are the better acid producers and are more common in commercial vinegar production, but their ability to oxidize acetic acid to carbon dioxide and water, a property which distinguishes them from Gluconobacter, can cause problems in some circumstances when the vinegar brewer will see his key component disappearing into the air as CO_2. Fortunately over-oxidation, as it is known, is repressed by ethanol and can be controlled by careful monitoring to ensure that ethanol is not completely exhausted during acetification. Most acetifications are run on a semi-continuous basis; when acetification is nearly complete and acetic acid levels are typically around 10–14% w/v, a proportion of the fermenter's contents is removed and replaced with an equal volume of fresh alcoholic vinegar stock. Since a substantial amount of finished vinegar is retained in the fermenter, this conserves the culture and means that a relatively high level of acidity is maintained throughout the fermentation, protecting against contamination. It also protects against over-oxidation as it has been found that *Acetobacter europaeus*, a species commonly found in commercial vinegar fermenters, will not over-oxidize when the acetic acid concentration is more than 6%.

10.4.8 Probiotics

Probiotics, or live microorganisms, are frequently utilized in various products such as food, drugs, and dietary supplements. The most commonly used probiotics are *Lactobacillus* and *Bifidobacterium* species, but other species such as yeast *Saccharomyces cerevisiae, E. coli*, and *Bacillus* species are also utilized. Lactic acid bacteria, including Lactobacillus species, have been utilized for thousands of years in food preservation through fermentation, offering dual benefits by acting as agents for food fermentation while also providing potential health benefits. Fermentation is a widely used process for preserving various raw agricultural materials such as cereals, tubers, fruits, vegetables, milk, and fish.

Lactic acid bacteria are Gram-positive, catalase-negative bacterial species that produce lactic acid as the primary end product of carbohydrate fermentation. Lactobacillus is a type of bacterium with many different species that typically live in our digestive, urinary, and genital systems without causing disease. Lactobacillus is also utilized to prevent and treat diarrhea associated with antibiotic use. Some people utilize lactobacillus for general digestion problems, irritable bowel syndrome (IBS), colic in babies, Crohn's disease, inflammation of the colon, and a severe gut problem called necrotizing enterocolitis (NEC) in premature babies.

Probiotics alter the microflora, secrete microbicidal substances, compete with pathogens to prevent their adhesion to the intestinal epithelium, compete for nutrients essential for pathogen survival, generate an antitoxin effect, and reverse some of the consequences of disease on the intestinal epithelium, such as secretory changes and neutrophil migration. Probiotics stimulate T-cells, B-cells, macrophages, and NK-cells with messages that promote specific immune responses. They also activate cytokines and phagocytic cells directly to coordinate their intelligent immune response.

Probiotics also produce various substances such as acetic acids, formic acids, lipopolysaccharides, peptidoglycans, superantigens, heat shock proteins, and bacterial DNA, in precise proportions to nourish each other, inhibit challengers, and/or benefit the host. Probiotics also produce antibacterial molecules called bacteriocins, such as lactolin produced by *Lactobacillus plantarum*, bulgarican secreted by *Lactobacillus bulgaricus*, and acidophilin, acidolin, bacterlocin, and lactocidin produced by *Lactobacillus acidophilus*. These and other antibacterial substances equip probiotic species with territorial mechanisms to combat and reduce pathologies related to *Shigella, Coliform, Pseudomonas, Klebsiella, Staphylococcus, Clostridium, Escherichia*, and other infectious genera.

10.5 GENETICALLY MODIFIED FOODS

Genetic modification is a special set of gene technology that alters the genetic machinery of such living organisms as animals, plants or microorganisms. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired trait very rapidly and with great accuracy. For example, plant geneticists can isolate a gene responsible for drought tolerance and insert that gene into a different plant. The new genetically-modified plant will gain drought tolerance as well. Not only can genes be transferred from one plant to another, but genes from non-plant organisms also can be used. Scientists first discovered in 1946 that DNA can be transferred between organisms. It is now known that there are several mechanisms for DNA transfer and that these occur in nature on a large scale, for example, it is a major mechanism for antibiotic resistance in pathogenic bacteria.

The first genetically modified (GM) plant was produced in 1983, using an antibiotic-resistant tobacco plant. China became the first countryin the world to commercialize a transgenic crop in the early 1990s with the introduction of virus resistant tobacco. In 1994, the transgenic ‘Flavour Saver tomato’ was approved by the Food and Drug Administration (FDA) for marketing in the USA. The best known example of this is the use of B.t. genes in corn and other crops. B.t., or *Bacillus thuringiensis*, is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. B.t. crystal protein genes have been transferred into corn, enabling the corn to produce its own pesticides against insects such as the European corn borer. While GM foods have potential benefits, such as increased yield, reduced pesticide use, and improved nutritional content, they also have potential risks, such as negative impacts on the environment and human health. It's important to continue researching and evaluating the safety and effectiveness of GM foods to ensure that they are safe and beneficial for consumers and the environment.

10.5.1 GM Crops

Genetic modification is a special set of gene technology that alters the genetic machinery of living organisms as animals, plants or microorganisms. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate. Genetic engineering, on the other hand, can create plants with the exact desired trait very rapidly and with great accuracy. For example, plant geneticists can isolate a gene responsible for drought tolerance and insert that gene into a different plant. The new genetically-modified plant will gain drought tolerance as well. Not only can genes be transferred from one plant to another, but genes from non-plant organisms also can be used. Scientists first discovered in 1946 that DNA can be transferred between organisms. It is now known that there are several mechanisms for DNA transfer and that these occur in nature on a large scale, for example, it is a major mechanism for antibiotic resistance in pathogenic bacteria. The first genetically modified (GM) plant was produced in 1983, using an antibiotic-resistant tobacco plant. China was the first country to commercialize a transgenic crop in the early 1990s with the introduction of virus resistant tobacco. In 1994, the transgenic 'Flavour Saver tomato' was approved by the Food and Drug Administration (FDA) for marketing in the USA. The best known example of this is the use of B.t. genes in corn and other crops. B.t., or *Bacillus thuringiensis*, is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. B.t. crystal protein genes have been transferred into corn, enabling the corn to produce its own pesticides against insects such as the European corn borer.

GM foods have been on the market for several decades, and many crops have been genetically modified, including corn, soybeans, cotton, canola, and sugar beets. These crops are widely used in processed foods, such as breakfast cereals, snack foods, and baked goods. In addition to crops, GM foods can also include animal products, such as salmon that has been genetically engineered to grow faster and larger. Some examples are discussed below:

- Corn: GM corn has been genetically modified to be resistant to pests and herbicides. This is done by introducing a gene from a bacterium called *Bacillus thuringiensis* (Bt) that produces a protein toxic to insects. When pests try to eat the GM corn, the protein is toxic to them, killing or deterring them from feeding. This can reduce the amount of pesticides needed to grow the crop and reduce damage from pests.
- Soybean: Soybeans have been genetically modified to be herbicide-tolerant, meaning they can withstand exposure to herbicides without being damaged. This is done by introducing a gene that produces an enzyme that breaks down the herbicide, allowing the soybean plant to survive while weeds are killed. This can make weed control easier and more effective, as farmers can use herbicides to kill weeds without harming the crop.
- Tomatoes: GM tomatoes have been engineered to have a longer shelf life. This is done by introducing a gene that slows down the ripening process, reducing the likelihood of spoilage and waste. This can have environmental benefits, as it can reduce food waste.
- Canola: Canola has been genetically modified to be herbicide-tolerant and produce higher yields than non-GM varieties. This is done by introducing genes that produce enzymes that break down the herbicide, allowing the canola plant to survive while weeds are killed. This can make weed control easier and more effective, as farmers can use herbicides to kill weeds without harming the crop. The increased yield can also help address global food security issues.
- Papaya: GM papaya varieties have been engineered to be resistant to the papaya ringspot virus, a

disease that can devastate papaya crops. This is done by introducing a gene that produces a protein that is toxic to the virus, allowing the papaya plant to survive and produce fruit.

- Potatoes: GM potatoes have been engineered to be resistant to bruising and produce less acrylamide, a potentially harmful chemical that forms when potatoes are cooked at high temperatures. This is done by introducing genes that produce enzymes that break down the starch in the potato, reducing the amount of acrylamide that forms during cooking.
- Rice: Rice has been developed to contain higher levels of vitamin A, which can help address vitamin A deficiency in developing countries. This is done by introducing a gene from a bacterium that produces beta-carotene, a precursor to vitamin A, which is then converted into vitamin A in the body.
- Salmon: GM salmon has been genetically engineered to grow faster and larger than non-GM salmon. This is done by introducing a gene from another fish species that controls growth hormone production, allowing the salmon to grow year-round instead of only during the warmer months.

10.5.2 Advantages of GM foods

- Pest resistance: Crop losses from insect pests can result in huge financial loss for farmers and starvation in developing countries. Farmers conventionally use large quantities of chemical pesticides annually. Consumers today are aware of potential health hazards associated withpesticides treated crops, moreover run-off of agricultural wastes from excessive use of pesticides and fertilizers can poison the water supply and cause harm to the environment. Growing GM foods can help eliminate the application of chemical pesticides and reduce the cost of production.
- Herbicide tolerance: Farmers typically use tilling for removal of weeds but for some crops, it is not cost-effective to remove weeds by these physical means so farmers often spray large quantities of different herbicides to destroy weeds, a time-consuming and expensive process, which requires care so that the herbicide doesn't harm the crop plant or the environment. Genetically-engineered crops to be resistant to one very powerful herbicide that could help prevent environmental damage by reducing the amount of herbicides needed.
- Disease resistance: There are many viruses, fungi and bacteria that cause plant diseases. Plant biologists are working to create plants with genetically-engineered resistanceto these diseases.
- Cold tolerance: Unexpected frost can destroy sensitive seedlings. An antifreeze gene from cold water fish has been introduced into plants such as tobacco and potato. With this antifreeze gene, these plants are able to tolerate cold temperatures that normally would kill unmodified seedlings.
- Drought tolerance/salinity tolerance: As the world population grows and productive land isreducing farmers will need to grow crops that can survive in adverse conditions. Creating plants that can withstand long periods of drought or high salt content in soil and groundwater will help people to grow crops in formerly inhospitable places.
- Nutrition: Malnutrition is common in third world countries where impoverished peoples rely on a single crop such as rice for the main staple of their diet which does not contain adequate amounts of all necessary nutrients to prevent malnutrition. For example, blindness due to vitamin A deficiency is a common problem in third world countries. Researchers at the Swiss Federal Institute of Technology Institute for Plant Sciences have created a strain of "golden" rice containing an unusually high content of beta-carotene (vitamin A).

- Pharmaceuticals: Medicines and vaccines often are costly to produce and sometimes require special storage conditions not readily available in third world countries. Researchers are working to develop edible vaccines in tomatoes and potatoes. These vaccines will be much easier to ship, store and administer than traditional injectable vaccines.

10.5.3 Risks associated with GM Foods

There are many controversies around GM foods, including whether food produced with it is safe, whether it should be labelled and if so how, whether it is needed to address world hunger now or in the future, and more specifically with respect to intellectual property and market dynamics, environmental effects of GM crops and GM crops' role in industrial agricultural more generally. Many issues like the risk of unintended harm to the environment, the health concerns that consumers should be aware of and the benefits of recombinant technology, also arise with pest-resistant and herbicide-resistant plants. The evolution of resistant pests and weeds termed superbugs and super weeds is another problem. Health risks associated with GM foods are concerned with toxins, allergens, or genetic hazards. The mechanisms of food hazards fall into three main categories i.e. they are inserted genes and their expression products, secondary and pleiotropic effects of gene expression and the insertional mutagenesis resulting from gene integration. With regards to the first category, it is not the transferred gene itself that would pose a health risk. It should be the expression of the gene and the effects of the gene product that are considered. New proteins can be synthesized that can produce unpredictable allergenic effects. For example, bean plants that were genetically modified to increase cysteine and methionine content were discarded after the discovery that the expressed protein of the transgene was highly allergenic. Due attention should be taken for foods engineered with genes from foods that commonly cause allergies, such as milk, eggs, nuts, wheat, legumes, fish, molluscs and crustaceans.

10.6 LET US SUM UP

This unit gave an understanding of fermentation process and outlined the history of fermentation. It introduced you to different types of fermented foods and explained about the microorganisms involved in preparation of these foods. The unit gave you an understanding about fermented milks, meat, fish, vegetables, vinegar, cheese as well as probiotics. The unit also introduced you to the concept of GM foods. The advantages and risks associated with use of GM foods were also explained in detail.

10.7 CHECK YOUR PROGRESS

1. Explain fermentation process.

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2. Write a short note on history of fermentation.

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3. Explain the role of microorganisms in preparation of alcoholic beverages.

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4. What is vinegar? How is it prepared?

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2 Write short notes on:

a) Probiotics

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a) Fermented Vegetables

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6. Explain role of fermentation process in cheese preparation.

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7. What are GM foods? What are advantages of GM crops?

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8. What are the risks associated with GM foods?

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SUGGESTED ONLINE LINKS

- *www.FDA/CFSAN FDA 2001- Food Code.*
- *www.FAO. Org*
- *Microbial diversity and systematic: 1075X_CH03_025.qxd (jblearning.com*
- *Microbiological Laboratory Techniques: Microbiological Laboratory Techniques (mowr.gov.in)*
- *Antibiotics and chemotherapeutic agents: Micro 260 Antibiotic agents and Modes of Action.pdf (spokane.edu)*
- *http://www.who.int/foodsafety/publications/fs_management/en/surface_decon.pdf*
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- *WHO website www. whoindia.org, www.who.int*
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