FOOD PROCESSING AND PACKGING TECHNOLOGY

M.Sc. FOOD AND NUTRITION SCIENCE

SEMESTER-II, PAPER-II

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FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining 'A+' grade from the NAAC in the year 2024, Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from over 221 affiliated colleges spread over the two districts of Guntur and Prakasam.

The University has also started the Centre for Distance Education in 2003-04 with the aim of taking higher education to the door step of all the sectors of the society. The centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even to housewives desirous of pursuing higher studies. Acharya Nagarjuna University has started offering B.Sc., B.A., B.B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A., and L.L.M., courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise in the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn be part of country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will go from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Coordinators, Editors and Lesson-writers of the Centre who have helped in these endeavors.

Prof. K. Gangadhara Rao
M.Tech., Ph.D.,
Vice-Chancellor I/c
Acharya Nagarjuna University.

M.Sc. FOOD AND NUTRITION SCIENCE
SEMESTER-II, PAPER-II
202FN24-FOOD PROCESSING AND PACKGING TECHNOLOGY
SYLLABUS

Course Objectives: To enable the students to

1) Knowledge of basic and applied aspects of food processing and technology
2) Knowledge of principles and methods of preservation
3) Knowledge of potential use of various by-products of food industry

THEORY

Unit-I:

- Food Processing and Preservation - Introduction. Need. Purpose and scope.
- Principles and Methods of food processing and preservation.
- Traditional Methods of food processing and preservation.
- Preservatives and Additives - Classification, applications, permissible limits and safety aspects.

UNIT II:

- Methods of Food Processing and Preservation: Processing and preservation by Heat - Principles of thermal processing
- Blanching, pasteurization, UHT processing, thermal sterilization, canning, extrusion. Processing and preservation by Cold- Refrigeration and freezing, methods of freezing, effect on quality of foods.
- Processing and preservation by Dehydration and Concentration - Types, Methods and their suitability for different food products.

UNIT III:

- Processing and Preservation by Fermentation: Definition, types, Importance, Technology, Benefits and Limitations.
- Processing and preservation of fermented foods - Cereal and pulse products. Vegetables, Milk products, Beverages, meat products.

UNIT IV:

- Processing and Preservation by Novel Methods: Pulsed X-rays, Microwave, Radio Frequency, Minimal Processing. Edible Coatings and Films, Membrane Processing, Hurdle Technology,
- Nanotechnology and Application in foods.
- New Food Products: New food product: Definition, Characteristics and Need for New food product development. Classification: Line extensions - Repositioning of existing products.
- New form of existing product - Reformulation - New packaging - Innovative products - Creative products and Value added products.

UNIT V:

- Packaging Materials: Definition, importance and scope of packaging of foods Origin of packaging materials.
- Types, properties, advantages & disadvantages of packaging materials
- Types of packaging material and their testing: Forms of packaging-box, bottle, tetra. pouch, shrink, vacuum, gas. CAP. MAP, asceptic etc.
- WVTR, GTR, bursting strength. tensile strength, tearing strength, drop test, puncture test. impact test etc.

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Course Outcomes: After completion of this course, students will be able to:

CO1: Learn about principles of processing and preservation

CO2: Generate new knowledge about the thermal, cold and dehydration methods of processing and preservation.

CO3: Understand the processing and preservation by fermentation techniques

CO4: Knowledge about processing and preservation by novel methods and development of new product

CO5: Importance and types of packaging materials

(202FN24)

M.Sc. DEGREE EXAMINATION, MODEL QUESTION PAPER
FIRST SEMESTER
FOOD PROCESSING AND PACKGING TECHNOLOGY

Time: Three hours **Maximum: 70 marks**

Answer ONE Question From Each Unit **5 × 14 = 70M**

Each Question Carries 14 Marks.

UNIT-I

1) Explain about different methods of food processing.

OR

2) Write about the permissible limits and safety aspects of additives.

UNIT-II

3) Enumerate the principles of thermal processing and pasteurization.

OR

4) Write the different methods of freezing and its effect on quality of foods.

UNIT-III

5) Write about any four novel methods of preservation.

OR

6) Describe the creative products and value added products? List the suitable examples.

UNIT-IV

7) Explain in detail about importance and benefits of preservation by fermentation.

OR

8) List the fermented food in milk products and Beverages? Explain the significances of fermentation

UNIT-V

9) Write the importance and scope of packaging of foods.

OR

10) Explain the role of packaging technology in food processing industries.

CONTENTS

LESSON-1

FOOD PROCESSING AND PRESERVATION - INTRODUCTION, NEED, PURPOSE AND SCOPE

1.0 OBJECTIVES:

- To introduce the concept and importance of converting raw food into safe, consumable products.
- To explain the purpose of improving shelf life, safety, taste and nutritional quality of food.
- To outline the scope of food processing and preservation in industry, economy and global food supply.
- To highlight the need for reducing food wastage, managing seasonal availability and ensuring food security.

STRUCTURE:

1.1 INTRODUCTION

Food is essential for human survival, but it is highly perishable and susceptible to spoilage due to microbial activity, chemical changes and physical deterioration. To ensure the availability, safety and quality of food from the point of production to consumption, food processing and preservation play a critical role.

1.2 FOOD PROCESSING

1.2.1 Definition

Food processing refers to the transformation of raw food materials into consumable products through physical, chemical or biological means. It includes all the steps taken from the time food is harvested to when it is served or packaged for sale.

1.2.2 Objectives of Food Processing

- Enhance shelf life and preserve nutrients
- Improve taste, texture and appearance
- Ensure safety by eliminating harmful microbes
- Add value to agricultural produce
- Facilitate storage, transportation and distribution
- Meet the demand for ready-to-eat or convenience foods

1.2.3 Levels of Food Processing

A. Primary Processing: Involves basic preparation of raw foods.

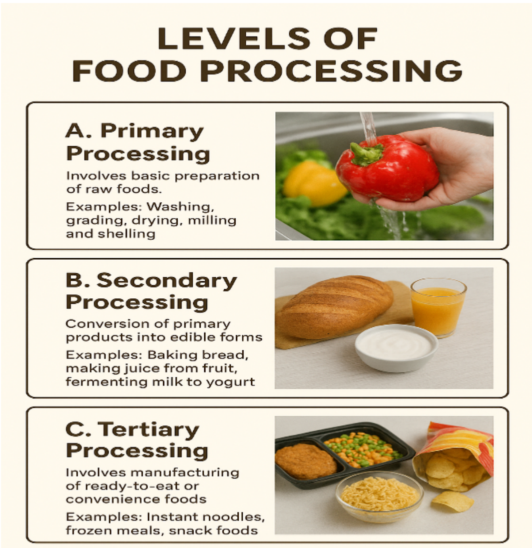
Examples: Washing, grading, drying, milling and shelling.

B. Secondary Processing: Conversion of primary products into edible forms.

Examples: Baking bread, making juice from fruit, fermenting milk to yogurt.

C. Tertiary Processing: Involves manufacturing of ready-to-eat or convenience foods.

Examples: Instant noodles, frozen meals, snack foods.



Levels of Food Processing

1.2.4. Common Food Processing Techniques

1) Mechanical Processes
2) Thermal Processing
3) Cold Processing
4) Chemical and Biochemical Processes
5) Packaging

1.2.5. Advantages of Food Processing

- Reduces food wastage
- Makes food more convenient and accessible
- Helps in year-round availability of seasonal foods
- Increases market value and economic return
- Supports food fortification (e.g., adding vitamins)

1.2.6. Disadvantages of Food Processing

- Loss of some nutrients (especially during heat treatments)
- Use of preservatives and additives may have health concerns
- Can lead to over-processing and reduced natural food value
- Sometimes high in salt, sugar and fat (in processed snacks or junk foods)

1.3 FOOD PRESERVATION

1.3.1 Definition

Food preservation is the process of treating and handling food in such a way that it slows down spoilage caused by microorganisms, enzymes and environmental factors. The main goal is to extend the shelf life of food while maintaining its safety, quality and nutritional value. Preservation techniques have been practiced for centuries, evolving from traditional methods to advanced scientific technologies.

Food Preservation

1.3.2. Objectives of Food Preservation

The primary aim of food preservation is to prolong the usability of food products. It helps reduce food waste, maintain nutritional quality, prevent the growth of harmful microorganisms and ensure food is available year-round regardless of season or location. Preservation is also important for commercial food distribution and storage.

1.3.3 Traditional Methods of Food Preservation

Traditional preservation techniques rely on physical and chemical means that have been used for generations. Drying is one of the oldest methods which removes moisture from food, preventing microbial growth. Salting and sugaring draw out moisture and create environments that inhibit bacteria and fungi. Pickling uses acid or brine to prevent spoilage. Smoking imparts both flavour and preservative properties through the exposure of food to smoke. Fermentation relies on beneficial microorganisms to produce acids or alcohol, which preserve the food naturally.

1.3.4 Modern or Scientific Methods of Food Preservation

Modern methods involve technology and controlled environments to preserve food. Refrigeration and freezing are common techniques that lower the temperature to slow down or stop microbial activity. Canning involves sealing food in airtight containers after heating it to destroy pathogens. Pasteurization heats liquids to a specific temperature for a short duration to kill harmful microbes without significantly affecting taste. Vacuum packing removes air from the packaging to prevent oxidation and microbial growth. Food irradiation uses controlled doses of ionizing radiation to kill bacteria and pests without making the food radioactive.

Preservatives, both natural and synthetic are often added to processed foods to prevent spoilage. Natural preservatives include salt, sugar, vinegar and citric acid. Chemical preservatives such as sodium benzoate or sulphur dioxide are used in regulated quantities to ensure safety and effectiveness.

1.3.5. Advantages of Food Preservation

Preservation makes food available for longer periods, reducing food loss and ensuring a stable food supply. It allows seasonal items to be consumed throughout the year. Many preservation methods also enhance convenience, making food easier to store, transport and prepare. Additionally, preserved foods can be fortified with essential nutrients, contributing to better nutrition.

1.3.6. Limitations of Food Preservation

Despite its benefits, food preservation can have drawbacks. Some methods may cause a loss of vitamins or minerals. The use of synthetic preservatives may raise health concerns in sensitive individuals. Over-processing can alter the texture, flavour and natural appearance of food. Moreover, certain preservation technologies require expensive equipment and energy, which may not be accessible everywhere.

1.4 NEED FOR FOOD PROCESSING

Food processing is essential for transforming raw food materials into safe, edible and marketable products. As food is naturally perishable and often inconvenient in its raw form, processing helps improve its quality, safety and accessibility. Below are the key reasons explaining the need for food processing in detail:

1. To Make Food Safe for Consumption

Raw foods can contain harmful microorganisms, parasites, or toxins. Processing methods like cooking, pasteurization, sterilization and irradiation help eliminate or reduce these hazards, making food safe to eat.

2. To Improve Shelf Life and Storage

Processing helps extend the life of perishable foods by reducing moisture, inactivating enzymes, or eliminating microbes. Methods such as drying, freezing, canning and vacuum packaging allow food to be stored for longer periods without spoilage.

3. To Enhance Taste, Appearance and Texture

Many raw foods are bland, tough, or unattractive in their natural form. Processing techniques like baking, frying, grinding, or emulsifying enhance the flavour, colour, aroma and texture of food, making it more appealing to consumers.

4. To Increase Convenience

Modern lifestyles demand quick and easy-to-prepare food. Food processing provides ready-to-eat or ready-to-cook products that save time and effort. Examples include instant noodles, pre-cut vegetables and frozen meals.

5. To Preserve Nutritional Quality and Add Value

Food processing can retain or even enhance nutritional value. Foods are often fortified with vitamins and minerals during processing. It also adds economic value by transforming low-cost raw materials into higher-value finished products.

6. To Reduce Post-Harvest and Handling Losses

Many crops are lost between harvest and consumption due to lack of proper processing. Converting fresh produce into jams, pickles, powders, or dried goods prevents waste and improves food availability.

7. To Make Seasonal and Regional Foods Available Year-Round

Processing allows the preservation and distribution of seasonal foods so that they can be consumed throughout the year and transported across regions without spoilage.

8. To Improve Digestibility and Edibility

Some raw foods are difficult to digest or consume. Processing helps break down tough structures (e.g., cooking legumes or cereals) and removes harmful substances, making food more digestible and palatable.

9. To Meet Consumer Demand and Lifestyle Changes

As lifestyles change, consumers prefer a variety of processed foods, including health-oriented, low-fat, gluten-free, or high-protein products. Processing meets these preferences through product innovation.

10. To Support Economic Growth and Employment

The food processing industry is a major sector that contributes to the economy by creating jobs, reducing food import dependence, supporting agriculture and promoting export of processed food products.

1.5. NEED FOR FOOD PRESERVATION

Food preservation is essential for ensuring the availability, safety and quality of food over time. As food is a perishable commodity, preserving it is crucial for both individual health and the sustainability of the global food system. Below are the major reasons that explain the need for food preservation in detail:

1. To Prevent Spoilage

Fresh food is prone to spoilage due to microbial growth, enzymatic activity, moisture, oxidation and other environmental factors. Preservation techniques help delay or stop these spoilage processes, ensuring food remains edible for longer.

2. To Extend Shelf Life

Preservation allows food to be stored for days, months, or even years without significant loss of quality. This is particularly important for perishable items like milk, meat, fruits and vegetables.

3. To Ensure Food Safety

Many preservation methods, such as pasteurization, refrigeration and canning, destroy or inhibit harmful microorganisms (like bacteria and molds) reducing the risk of foodborne illnesses.

4. To Reduce Post-Harvest Losses

In agricultural sectors, a significant amount of food is wasted due to poor storage and spoilage after harvest. Preservation techniques help reduce these losses, making more food available for consumption.

5. To Maintain Nutritional Value

Food preservation helps retain essential nutrients, especially when done using controlled and appropriate methods. Even preserved foods can serve as important sources of vitamins, minerals and energy.

6. To Meet Seasonal Demand

Preservation makes it possible to enjoy seasonal fruits and vegetables even when they are not naturally available, by storing or processing them for later use.

7. To Ensure Food Availability During Emergencies

Preserved food is vital for use during emergencies like natural disasters, wars, or pandemics when fresh food supply is limited. It ensures food security and reduces dependency on daily harvests or production.

8. To Support Transportation and Trade

Food that is preserved can be transported over long distances without spoilage. This supports international food trade and makes exotic or non-local foods available in distant markets.

9. To Add Economic Value

Preserved foods often undergo value addition, turning raw produce into products like jams, juices, dried snacks, or frozen meals. This boosts income for farmers, producers and businesses.

10. To Minimize Food Wastage at Consumer Level

Properly preserved food gives consumers more time to use it before it spoils. This reduces food waste in households, restaurants and stores.

1.6 PURPOSE OF FOOD PROCESSING

Food processing involves converting raw food materials into usable, edible, or value-added food products. The main purposes of food processing are:

1. To Make Food Safe for Consumption

Processing helps eliminate harmful microorganisms, parasites and toxins that may be present in raw foods. Techniques like pasteurization, sterilization and cooking kill pathogens and reduce the risk of foodborne diseases.

2. To Improve Shelf Life and Reduce Spoilage

By using methods like drying, canning, freezing, or vacuum sealing, food processing slows down spoilage caused by microbes, enzymes and oxidation, thus extending the shelf life of perishable items.

3. To Enhance Taste, Appearance and Texture

Processing improves the sensory qualities of food - flavor, aroma, color and texture making it more appealing and enjoyable. For example, baking enhances taste and emulsification improves texture.

4. To Increase Convenience

Processed foods often require less preparation time and effort. Ready-to-eat meals, instant noodles, frozen vegetables and pre-cut fruits save time for consumers and meet modern lifestyle needs.

5. To Preserve Nutritional Quality

Many processing methods help retain essential nutrients. Some foods are also fortified during processing with added vitamins and minerals (like iodized salt or fortified flour), improving their nutritional value.

6. To Make Food Available Year-Round

Processing allows seasonal foods to be stored and consumed even when they are out of season. It ensures a steady food supply irrespective of harvest cycles or regional limitations.

7. To Reduce Food Waste

By processing excess, damaged, or surplus produce into products like juices, sauces, or jams, food that would otherwise go to waste is converted into usable products.

8. To Improve Digestibility and Edibility

Processing can break down complex food structures, making them easier to digest or eat. For example, cooking softens vegetables and legumes and milling turns grains into flour.

9. To Add Economic Value

Processed foods can be sold at a higher value than raw products. Processing also supports industrial growth, job creation and trade by adding variety and marketability to food items.

10. To Standardize Quality

Food processing ensures uniformity and consistency in taste, texture, weight and appearance, which is important for branding and consumer trust.

1.7 PURPOSE OF FOOD PRESERVATION

The purpose of food preservation is to extend the shelf life of food, maintain its safety and retain its nutritional, sensory and functional qualities over time. Here are the key objectives in detail:

1. To Prevent Food Spoilage

Food is susceptible to spoilage due to microorganisms (bacteria, fungi, yeasts), enzyme activity and chemical reactions such as oxidation. Preservation methods prevent or slow down these processes, ensuring food remains fresh and safe for longer periods.

2. To Extend Shelf Life

Preservation techniques allow food to be stored for days, weeks, months, or even years without spoiling. This is essential for reducing food waste and ensuring availability during transportation, storage, or seasonal shortages.

3. To Maintain Nutritional Value

Preservation helps retain essential nutrients such as vitamins, minerals and proteins. While some methods may cause slight nutrient loss, controlled techniques are designed to preserve as much nutrition as possible.

4. To Ensure Food Safety

Many preservation methods like pasteurization, canning, freezing and irradiation are designed to kill or inhibit harmful microorganisms that can cause foodborne illnesses.

5. To Enhance Food Security

Preserved food can be stored and used during times of scarcity, poor harvest, natural disasters, or emergencies. It ensures a stable and reliable food supply throughout the year.

6. To Improve Convenience

Preserved foods are often pre-processed or ready-to-eat, saving time and effort for consumers. This supports busy modern lifestyles and urban living.

7. To Support Global Trade and Distribution

Preservation enables long-distance transportation of food across regions and countries. It makes it possible to enjoy seasonal or exotic foods year-round and supports international food commerce.

8. To Enhance Appearance, Taste and Texture

Certain preservation techniques also help improve or maintain the sensory properties of food such as color, flavor and consistency, making it more appealing and marketable.

9. To Add Economic Value

Preserved food products can be sold at higher value, create job opportunities in food industries and support small and large-scale food businesses through extended market reach.

10. To Reduce Post-Harvest Losses

Especially in agricultural settings, food preservation helps reduce the amount of food that is lost after harvest due to spoilage, pests, or environmental conditions.

1.8 SCOPE OF FOOD PROCESSING

The scope for food processing is extensive and continually expanding due to increasing population, urbanization, technological advancement, rising consumer demand for convenient and nutritious foods and the need to reduce post-harvest losses. It plays a key role in enhancing food security, economic development and employment generation. Here's a detailed overview of the scope:

1. Growing Consumer Demand

Modern lifestyles have led to a shift in eating habits. There is high demand for processed, ready-to-eat and ready-to-cook foods such as frozen snacks, instant meals and packaged juices. This demand is expected to grow significantly in the coming years.

2. Reduction of Post-Harvest Losses

A large portion of agricultural produce is lost due to poor handling and lack of processing. Food processing helps reduce these losses by converting perishable raw materials into shelf-stable, value-added products.

3. Value Addition to Raw Materials

Food processing enhances the economic value of agricultural produce. For example, tomatoes can be turned into ketchup, mangoes into pulp or juice and milk into cheese or butter, providing higher returns for farmers and industries.

4. Employment and Entrepreneurship Opportunities

The food processing sector supports rural and urban employment through small-medium and large-scale enterprises. It encourages entrepreneurship in areas such as bakery, dairy, fruit and vegetable processing and spice packaging.

5. Boost to Export Potential

Processed and packaged food products are in demand in international markets. India and other agricultural countries have great potential to export pickles, spices, frozen foods, beverages and snacks, contributing to foreign exchange earnings.

6. Support for Food Security and Nutrition

Food processing ensures year-round availability of nutritious and safe food. It helps in fortifying foods with essential vitamins and minerals, supporting efforts to combat malnutrition and improve public health.

7. Development of Rural Economy

Agro-based processing units in rural areas can uplift local economies by creating income opportunities for farmers, women and self-help groups. This also reduces migration to urban centres.

8. Technological Innovations

New technologies like cold chain logistics, automation, robotics, high-pressure processing, vacuum drying and smart packaging are expanding the capabilities of food processing while maintaining safety, hygiene and efficiency.

9. Government Support and Policies

Many governments (including India's) are promoting food processing through schemes, subsidies, mega food parks and infrastructure development. This supportive environment increases the sector's growth potential.

10. Sustainability and Waste Utilization

The sector is exploring sustainable practices like using food waste for biofuel, compost, or animal feed. Processing also helps reduce the carbon footprint by reducing food spoilage and improving supply chain efficiency.

11. Research and Development

Continuous innovation in food science, preservation techniques, packaging and health-oriented food products opens up new opportunities for researchers, technologists and investors.

1.9 SCOPE OF FOOD PRESERVATION

The scope for food preservation is broad and growing, driven by population growth, changing consumer lifestyles, global food trade and the need to reduce food waste. It spans traditional practices to modern industrial technologies and plays a key role in ensuring food security, nutrition and sustainability. Here's a detailed explanation of the various areas where food preservation has significant scope:

1. Increasing Demand for Processed and Preserved Foods

Urbanization and busy lifestyles have increased the demand for ready-to-eat, shelf-stable and convenience foods. Preserved foods such as frozen vegetables, canned fruits, pickles and dehydrated meals are in high demand in both domestic and international markets.

2. Agricultural Surplus Utilization

Food preservation provides a solution to handle seasonal gluts of fruits, vegetables and cereals. By processing and preserving them, the surplus is converted into value-added products like jams, juices and powders preventing post-harvest losses and stabilizing farmer incomes.

3. Support for Food Security

Preservation extends the shelf life of food, making it available during off-seasons, natural disasters and emergencies. It ensures a stable supply of essential food items even when fresh produce is not readily accessible.

4. Growth of Food Industries and Employment

Food preservation is a foundation of the food processing industry. It supports the development of small-medium and large-scale enterprises in rural and urban areas, generating employment and promoting entrepreneurship.

5. Expansion of International Food Trade

Preserved food items can be transported over long distances without spoilage, allowing for the global export and import of food products. This helps countries access diverse foods and boosts export income.

6. Technological Advancements

Innovations like vacuum packaging, high-pressure processing (HPP), cold plasma and food irradiation have expanded the possibilities for safe and efficient food preservation. These methods maintain food quality and nutritional value while meeting modern safety standards.

7. Reduction of Food Waste

Globally, a significant percentage of food is wasted due to spoilage. Preservation techniques can reduce food waste at every stage from farm to retail to household by keeping food fresh longer.

8. Nutritional and Functional Food Development

Preservation helps retain nutrients in food and allows for fortification with essential vitamins and minerals. This opens up the scope for developing fortified and functional foods that can help combat malnutrition.

9. Preservation of Traditional Foods and Cultural Heritage

Traditional food preservation techniques like pickling, fermentation and sun-drying help retain cultural food practices and promote regional specialties in global markets.

10. Environmental Sustainability

By reducing food spoilage and wastage, preservation contributes to more sustainable Gfood systems. It minimizes the need for excessive farming and reduces the environmental impact of food production.

11. Scope in Research and Education

Food preservation offers opportunities for research in microbiology, biotechnology, packaging and nutrition. It is also a key subject in food science education and training programs.

1.10 CONCLUSION:

Food processing and preservation are essential components of the modern food industry, addressing the fundamental need to extend shelf life, maintain nutritional value, enhance safety and reduce food wastage. The introduction highlights the transformation of raw food into consumable products, while the purpose emphasizes improving food quality, accessibility and sustainability. The scope reflects the vast potential of this sector in supporting food security, economic growth and technological innovation. Lastly, the need for food processing and preservation arises from growing populations, seasonal availability of produce, and the demand for convenient, safe and nutritious food. Together, these elements underscore the critical role of food processing and preservation in ensuring a reliable and efficient global food system.

1.11 SUMMARY:

Food processing and preservation involve converting raw food materials into safe, nutritious and longer-lasting products. The introduction sets the foundation by explaining their role in enhancing food quality and usability. The purpose is to ensure food safety, improve taste and texture, reduce spoilage and meet consumer needs. The scope extends across agriculture, industry, health and economy, offering opportunities for innovation, employment and global food distribution. The need arises from factors like population growth, seasonal food availability and the demand for ready-to-eat or long-lasting products. Together, they contribute significantly to food security and sustainable development.

1.12 TECHNICAL TERMS:

Fermentation**,** Pasteurization**,** Canning**,** Dehydration (Drying)**,** Irradiation**,** Hazard Analysis Critical Control Point (HACCP)

1.13 SELF ASSESSMENT QUESTIONS:

1) What is food processing and why is it important?
2) Define food preservation and list two common methods.
3) What are the main purposes of food processing?
4) What is the scope of food processing in the modern food industry?
5) Why is there a growing need for food preservation today?

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Dr. Santhi Sri, K.V

LESSON-2

PRINCIPLES AND METHODS OF FOOD PROCESSING AND PRESERVATION

2.0 OBJECTIVES:

- To Extend Shelf Life and Ensure Food Safety
- To Preserve Nutritional Value
- To Minimize Post-Harvest Losses
- To Facilitate Storage, Distribution and Transportation
- To Support Food Security and Sustainability

STRUCTURE:

2.1 INTRODUCTION

Food processing and preservation are essential practices in the food industry that ensure the availability of safe, nutritious and high-quality food products throughout the year. These practices play a critical role in reducing food spoilage, extending shelf life and maintaining the sensory and nutritional qualities of food.

Food processing involves transforming raw ingredients into consumable food products through various physical, chemical, or biological techniques. Preservation, on the other hand, focuses on methods that prevent or slow down the deterioration of food caused by microbial activity, enzymatic changes, or chemical reactions.

The principles of food processing and preservation are based on scientific methods that aim to:

- Inhibit microbial growth
- Inactivate food-degrading enzymes
- Prevent oxidation and other spoilage reactions
- Protect food from physical and chemical damage.

To achieve these objectives, various methods are employed, including thermal treatments (like pasteurization and sterilization), refrigeration, freezing, drying, fermentation, chemical preservatives and advanced technologies such as irradiation and high-pressure processing.

Together, these principles and methods help ensure food safety, reduce post-harvest losses, support food security and provide consumers with convenient and ready-to-eat products.

2.2 HIGH TEMPERATURE METHOD OF FOOD PRESERVATION

Principle:

The high temperature method of food preservation works on the principle of destroying or inactivating spoilage and pathogenic microorganisms (bacteria, yeasts, molds) as well as enzymatic activity that causes deterioration in food. When food is exposed to elevated temperatures for a specific time, the heat denatures microbial proteins, enzymes and nucleic acids, leading to the death of microorganisms or inactivation of their functions. This process increases the shelf life of food and ensures safety for consumption.

Methods of High Temperature Preservation:

There are three main techniques under high temperature preservation:

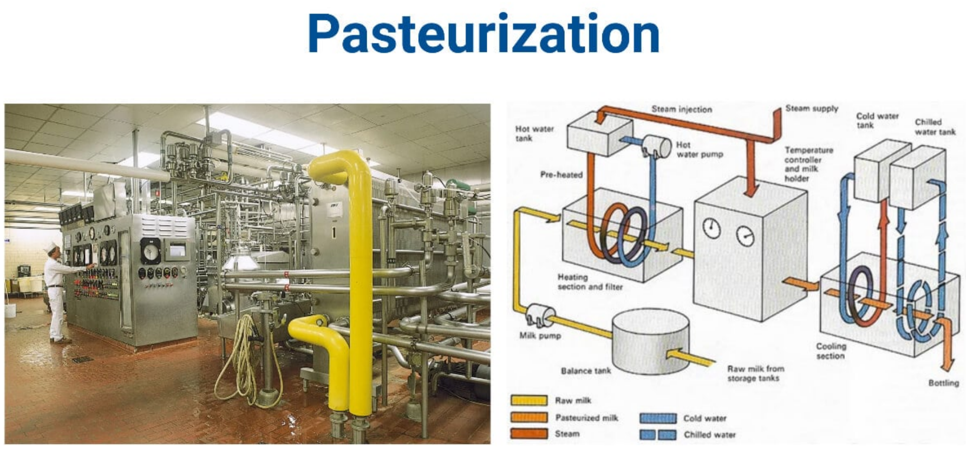
1. Pasteurization

Pasteurization is the process of heating food (especially liquids like milk or juice) to a moderate temperature (typically 60°C to 85°C) for a short time (from a few seconds to several minutes) and then quickly cooling it. It kills non-spore-forming pathogens and spoilage organisms, but does not kill all microbes.

Applications: Milk, fruit juices, beer, wine, vinegar and liquid eggs.

Types:

- Low-Temperature Long-Time (LTLT) – e.g., 63°C for 30 min.
- High-Temperature Short-Time (HTST) – e.g., 72°C for 15 sec.
- Ultra-Pasteurization – e.g., 135°C for 2 sec (used in UHT milk).



Pasteurization

2. Boiling and Blanching

Boiling involves heating food in water at 100°C for a short period. Blanching involves briefly immersing food (mostly vegetables or fruits) in boiling water or steam, then cooling rapidly. It helps to kill surface microorganisms and inactivate enzymes before further processing (like drying, freezing, or canning).

Applications: Vegetables before freezing, tomatoes before peeling and leafy greens to reduce microbial load.

3. Canning / Sterilization

Canning is the method of sealing food in airtight containers and heating to 110°C to 121°C under pressure to achieve commercial sterility. It kills both vegetative cells and bacterial spores, making food shelf-stable for months or even years without refrigeration.

Applications: Vegetables, meat, fish, fruits, soups and ready-to-eat meals.

Advantages of High Temperature Preservation:

- Destroys or inactivates most microbes and enzymes.
- Retains most of the nutrients if applied properly (especially pasteurization).
- May cause texture or flavor changes at very high temperatures (e.g., in canning).
- Safe, chemical-free method used widely in both home and industrial processing.

2.3 LOW TEMPERATURE METHOD OF FOOD PRESERVATION

Principle:

The low temperature method of food preservation is based on the principle that lowering the temperature slows down or stops the growth and activity of microorganisms (bacteria, yeasts, molds) and inhibits enzymatic reactions that lead to food spoilage.

Microorganisms need warmth, moisture and nutrients to grow. By reducing the temperature, the environment becomes unfavourable for microbial growth and the chemical and enzymatic reactions responsible for food deterioration are slowed down.Low temperature doesn't usually kill microbes, but it slows their activity, thereby delaying spoilage and extending shelf life.

Methods of Low Temperature Preservation:

Low temperature preservation mainly includes refrigeration, chilling and freezing, each using different temperature ranges and suitable for different food types.

1. Refrigeration:

Storing food at temperatures between 0°C and 4°C slows down the growth of spoilage microorganisms and enzymatic reactions.

Applications: Milk, meat, fish, cooked food, fruits, vegetables and dairy products.

Refrigeration

2. Chilling

Chilling involves reducing the temperature of food to just above its freezing point, usually between -1°C and 1°Cextends shelf life more effectively than refrigeration while still keeping food in a fresh state.

Applications: Meat, poultry, seafood and certain fresh produce (like berries and lettuce).

3. Freezing

Freezing is the process of lowering the temperature of food to below -18°C, causing water in the food to form ice crystals. Stops microbial activity entirely and significantly slows down enzyme actions.

Applications: Vegetables, fruits, meats, fish, ready-to-cook items, bakery products.

2.4 CHEMICAL METHOD OF FOOD PRESERVATION

Principle:

The chemical method of food preservation is based on the principle of using specific chemical substances (called preservatives) to inhibit the growth of microorganismssuch as bacteria, yeasts and moldsor to delay chemical reactions like oxidation that cause food spoilage.

These substances either kill the microorganisms or prevent them from multiplying and may also work by inactivating enzymes, reducing acidity (pH), or removing available water in the food environment.

Method: In chemical preservation, approved food-grade chemicals are added to foods either during processing or packaging. These chemicals can be natural (like salt or vinegar) or synthetic (like sodium benzoate or potassium sorbate). The method involves:

- Selection of Preservative
- Addition of the Chemical Preservative
- Mixing or Application
- Packaging and Storage

Salt Preservation

Examples of Common Chemical Preservatives and Their Uses:

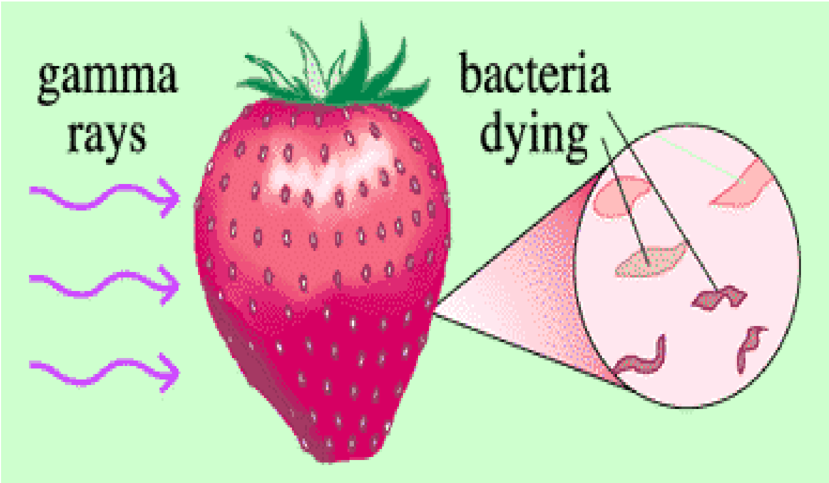
- Salt – Used in pickles, cured meats and fish. Works by drawing out water and creating a salty environment that inhibits microbial growth.
- Vinegar (Acetic acid) – Used in chutneys, pickles and sauces. Lowers the pH to levels where microbes cannot survive.
- Sugar – Preserves fruits, jams and jellies by binding water and making it unavailable for microbial use.
- Sodium benzoate – Commonly used in acidic foods like fruit juices and soft drinks. Inhibits yeast and mold growth.
- Potassium sorbate – Used in cheese, yogurt and baked goods. Inhibits mold and some bacteria.
- Sulphur dioxide (SO_2) – Used in dried fruits and wines. Prevents browning and microbial spoilage.
- Nitrates and nitrites – Used in processed meats to prevent bacterial growth (especially *Clostridium botulinum*) and preserve color.

2.5 IRRADIATION METHOD OF FOOD PRESERVATION

Principle:

The irradiation method of food preservation is based on the use of ionizing radiation (such as gamma rays, X-rays, or electron beams) to kill or inactivate microorganisms, insects and parasites in food and to delay ripening or sprouting. This method does not make food radioactive; rather, it breaks down DNA or cellular structures of harmful organisms, preventing their reproduction and survival.

The main goal is to extend shelf life, enhance safety and maintain quality without the use of chemical preservatives or high temperatures.



Irradiation

Method of Irradiation Preservation:

Irradiation is carried out in specialized, licensed facilities equipped with controlled sources of radiation. The process involves the exposure of food to precise doses of ionizing radiation.

1. Selection and Preparation of Food
2. Exposure to Ionizing Radiation
   - Low dose (up to 1 kGy): to inhibit sprouting and kill insects.
   - Medium dose (1–10 kGy): to reduce spoilage organisms and delay ripening.
   - High dose (above 10 kGy): to sterilize food for long-term storage.
3. Packaging and Labelling
4. Storage and Distribution

Applications of Food Irradiation:

- Spices and herbs: Sterilized without heat.
- Grains and pulses: Protected from insect infestation.
- Fruits and vegetables: Delayed ripening and sprouting.
- Meat and poultry: Reduced bacterial contamination (e.g., *Salmonella*).
- Seafood: Prolonged freshness and safety.

Advantages:

- Destroys harmful microorganisms without affecting taste, color, or texture.
- Non-thermal process, preserving heat-sensitive nutrients and qualities.

- Reduces chemical usage like fumigants or preservatives.
- Increases shelf life and food safety, especially in global food trade.

Limitations and Considerations:

- Requires specialized equipment and safety protocols.
- Not effective against toxins already present (e.g., aflatoxins).
- Public scepticism and regulatory limits exist in some countries.
- Over-irradiation can affect flavor or texture in some foods.
- Foods must be hygienically handled before and after to avoid recontamination.

2.6 DRYING METHOD OF FOOD PRESERVATION

Principle:

The drying method of food preservation is based on the principle of removing moisture (water content) from the food to a level that inhibits the growth of spoilage microorganisms and slows down enzymatic and chemical reactions.

Since microorganisms like bacteria, molds and yeasts require water for survival and reproduction, reducing the water activity in food creates an environment where they cannot grow or survive, thereby preserving the food for extended periods.

Method of Drying:

Drying can be done through natural (traditional) or mechanical (modern/controlled) methods. The process generally includes several steps:

1. Selection and Preparation of Food
2. Removal of Moisture

Common drying methods include

a) Sun Drying (Traditional)

b) Shade Drying

c) Mechanical/Dehydrator Drying

d) Spray Drying and Freeze Drying (Industrial Methods)

3. Cooling and Packaging
4. Storage

Sun Drying

Advantages of Drying Method:

- Extends shelf life without refrigeration.
- Lightweight and compact, making storage and transport easier.
- Preserves nutrients, especially when done at low temperatures.
- Prevents waste of seasonal surplus produce.
- Economical and easy to apply, even at household level.

Limitations:

- Improper drying can lead to mold growth or spoilage.
- Exposure to high temperatures may reduce some heat-sensitive nutrients (e.g., vitamin C).
- Traditional sun drying is weather dependent and prone to contamination.
- May alter texture and flavor, especially in fruits and meat.

2.7 FERMENTATION METHOD OF FOOD PRESERVATION

Principle:

The fermentation method of food preservation is based on the principle of using beneficial microorganisms (such as bacteria, yeasts, or molds) to convert sugars and other carbohydrates in the food into acids, gases, or alcohol. These by-products create an environment that inhibits the growth of spoilage or pathogenic microbes, thus preserving the food.

In most cases, lactic acid bacteria (LAB) are responsible for producing lactic acid, which lowers the pH of the food, making it too acidic for harmful microorganisms to survive. In other types of fermentation, yeasts produce alcohol which acts as a natural preservative.

Fermentation

Method of Fermentation:

Fermentation involves controlled microbial activity under specific conditions. The method varies depending on the type of food and desired final product but generally follows these steps:

- Selection and Preparation of Raw Materials
- Inoculation or Natural Fermentation
- Fermentation Process
- Monitoring and Completion
- Packaging and Storage

Examples of Fermented Foods:

- Vegetables: Sauerkraut (fermented cabbage), kimchi.
- Cereals/legumes: Idly, dosa batter, dhokla, soy sauce.
- Dairy: Yogurt, curd, kefir, cheese.
- Beverages: Wine, beer, kombucha.
- Other: Pickles, vinegar, fermented fish or meat in some cultures.

Advantages of Fermentation:

- Extends shelf life without artificial preservatives.
- Enhances nutritional content, especially B vitamins and probiotics.
- Improves digestibility by breaking down complex nutrients.
- Adds unique flavours and textures.
- Often requires simple equipment and can be done at home.

Limitations:

- Fermentation needs strict hygiene and temperature control to avoid contamination.
- Some people may be sensitive to fermented foods due to histamines or other by-products.
- Fermented products may continue to ferment if not refrigerated, affecting taste or causing gas build-up.
- Time-consuming compared to other preservation methods.

2.8 SUGAR METHOD OF FOOD PRESERVATION

Principle:

The sugar method of food preservation is based on the principle of using high concentrations of sugar to create an environment that is inhospitable to microbial growth.

Sugar acts as a preservative by drawing out water from the food and from any microorganisms present, through a process called osmosis. When the water content is reduced, microbial cells become dehydrated and their growth is inhibited or completely stopped. Additionally, sugar binds the available water in the food, making it unavailable for microbial activity.

This method is especially effective for preserving fruits, which naturally contain sugars and acids that enhance the preservative effect.

Sugar Preservation

Method of Sugar Preservation:

The sugar preservation method involves several stages where sugar is applied or incorporated into food to reduce its water activity and enhance its longevity.

1. Selection and Preparation of Food

2. Addition of Sugar

   There are multiple ways sugar is used for preservation:

   a) Making Sugar Syrup:

   b) Dry or Raw Sugar Packing:

   c) Concentrated Products (Jams, Jellies, Marmalades):

3. Cooking or Processing (If Applicable)

4. Cooling and Packaging

Advantages of Sugar Preservation:

- Increases shelf life naturally without artificial chemicals.
- Improves taste by adding sweetness.
- Retains color and flavor, especially in fruits.
- Suitable for homemade and commercial food products.

Limitations:

- High sugar intake is not suitable for people with diabetes or dietary restrictions.
- Sugar-preserved foods can ferment if sugar concentration is too low or if moisture is reabsorbed.
- Improper sealing can lead to mold growth.
- Not suitable for all types of foods (mainly used for fruits and sweet condiments).

2.9 ACIDS METHOD OF FOOD PRESERVATION

Principle:

The acid method of food preservation is based on the principle that acidity (low pH) creates an unfavourable environment for spoilage and pathogenic microorganisms. Most bacteria cannot survive or grow in acidic conditions, particularly at a pH below 4.6.

Acids can be naturally present, produced by fermentation, or added artificially to foods. They inhibit enzyme activity, slow microbial metabolism and alter microbial cell membranes, thus preserving the food and extending its shelf life.

Method of Acid Preservation:

The method of acid preservation depends on whether the acid is naturally formed, added directly, or used in combination with other preservation techniques.

1. Selection and Preparation of Food

2. Acidification Process

There are three main approaches:

a) Natural Acids in Food

b) Fermentation-Produced Acids

c) Addition of Acids (Artificial Acidification)

3. Filling and Packaging

4. Storage

Citric Acid Preservation

Advantages of Acid Preservation:

- Effectively inhibits spoilage organisms, including pathogens like *Clostridium botulinum.*
- Enhances flavor with tangy, sour taste.
- Boosts food safety, especially in canned and bottled products.
- Suitable for home and industrial processing.

Limitations:

- Not suitable for all types of foods, especially those with high fat or protein content (like raw meat).
- Excess acidity can affect taste and digestibility.
- Mildly acidified foods need refrigeration or pasteurization for safety.
- Requires careful control of acid concentration and pH to ensure effectiveness.

2.10 SALT METHOD OF FOOD PRESERVATION

Principle:

The salt method of food preservation works on the principle of osmosis, dehydration and reduction in water activity. Salt (sodium chloride) draws water out of microbial cells and food tissues, thereby inhibiting or destroying spoilage-causing microorganisms such as bacteria, yeasts and molds. Salt also creates a hypertonic environment where microbial cells lose water and shrink (plasmolysis), which prevents them from growing and reproducing. This reduces the chance of spoilage and extends the shelf life of food.

Salt Preservation

Method of Salt Preservation:

The salt preservation method varies depending on the food and the desired product, but it typically involves the following steps:

1. Selection and Preparation of Food

2. Application of Salt

   There are two major techniques for salting food:

   a) Dry Salting

   b) Brine Salting (Wet Salting)

3. Fermentation (Optional Step in Some Cases)

4. Draining and Drying (For Some Products)

5. Packaging and Storage

Factors Affecting Salt Preservation:

- Salt concentration: Higher salt content results in better preservation but may affect taste.
- Temperature: Cooler storage slows down any remaining microbial activity.
- Food thickness and type: Thicker or dense foods require longer salting or higher concentrations.
- Cleanliness: Hygiene is crucial to prevent contamination.

Examples of Salt-Preserved Foods:

- Meat and fish: Salted fish, salted pork, jerky.
- Vegetables: Pickled mango, lemon, cucumber.
- Dairy: Salted butter, cheese (e.g., feta).
- Other: Sauerkraut, olives, tamarind.

Advantages of Salt Preservation:

- Simple and low-cost method.
- Effective in areas without refrigeration.
- Enhances flavor in many traditional foods.
- Can be combined with other methods (e.g., drying, fermentation).

Limitations:

- High salt intake is a health concern, especially for those with hypertension or kidney issues.
- Over-salting may affect the palatability of food.
- Not suitable for all foods, especially fruits.
- Salt-tolerant microbes (like some molds and bacteria) can still grow if hygiene is poor or salt is insufficient.

Preservation by Salting

2.11 CONCLUSION:

The principles and methods of food processing and preservation are foundational to maintaining the quality, safety and availability of food from the point of harvest to the point of consumption. These principles are based on scientific understanding of how food deteriorates and what interventions can be applied to slow down or stop spoilage processes caused by microorganisms, enzymes and environmental factors such as temperature, light, and moisture.

Food processing methods, such as cooking, pasteurization, sterilization, drying, fermentation and packaging, help in enhancing the palatability, digestibility and shelf life of food. Similarly, preservation techniques such as refrigeration, freezing, canning, use of chemical preservatives and irradiation ensure that food remains safe for consumption over extended periods without significant loss of quality or nutritional value.

These methods aim to:

- ❖ Inhibit microbial growth
- ❖ Delay enzymatic activity
- ❖ Prevent oxidation and contamination
- ❖ Reduce food loss and waste
- ❖ Enable wider distribution and storage.

In today's world, where population growth, urbanization and climate change pose increasing challenges to food supply and security, food processing and preservation are more important than ever. They contribute not only to feeding a growing global population but also to reducing hunger, improving nutrition, supporting the economy and promoting sustainability.

2.12 SUMMARY:

The principles and methods of food processing and preservation are essential for ensuring food remains safe, nutritious and suitable for consumption over time. These approaches help in extending the shelf life of food, maintaining its quality and preventing spoilage caused by microorganisms, enzymes and environmental factors.

Key principles include controlling microbial growth, inactivating spoilage-causing enzymes, preventing oxidation and protecting food from physical damage.

Common methods used for processing and preservation include:

- Physical methods like heating (pasteurization, sterilization), cooling (refrigeration, freezing), drying and irradiation.
- Chemical methods using preservatives, acids and antioxidants.
- Biological methods such as fermentation.

These methods help in improving food safety, reducing post-harvest losses, increasing convenience and supporting year-round food availability. Overall, they play a vital role in modern food systems by ensuring food security, quality and sustainability.

2.13 TECHNICAL TERMS:

Pasteurization, High-Pressure Processing (HPP), Freeze-Drying (Lyophilization), Hurdle Technology, Vacuum Packaging, Irradiation

2.14 SELF ASSESSMENT QUESTIONS:

1) Explain in detail the basic principles involved in food preservation. How do these principles help in extending the shelf life of food products?
2) Discuss the various physical methods used in food preservation.
3) What are chemical preservatives? Classify them and explain their mechanism of action with examples.
4) Discuss the role of refrigeration and freezing in food preservation.

2.15 REFERENCE BOOKS:

- *P. J. Fellows - Food Processing Technology: Principles & Practice, 5th ed. (Woodhead/Elsevier, 2022)*
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- *Narender Raju Panjagari - Principles of Food Processing & Preservation (INFLIBNET e-book, 2018)*
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LESSON-3

TRADITIONAL METHODS OF FOOD PROCESSING AND PRESERVATION

3.0 OBJECTIVES:

After going through this lesson, students will be able to:

- .Understand the need for food processing and preservation
- Identify common traditional methods like drying, fermentation and pickling
- Explain how traditional methods help in keeping food safe and lasting longer
- Compare traditional and modern preservation techniques
- Recognize the cultural importance of traditional food practices

STRUCTURE:

3.1 INTRODUCTION

For centuries, people have used simple and natural methods to preserve food and make it safe to eat over time. Before modern technology was developed, communities depended on traditional practices such as sun drying, fermenting, pickling and smoking to prevent food from spoiling. These techniques not only extended the shelf life of food but also added unique flavours and sometimes improved nutritional value.

Traditional food preservation methods are cost-effective, eco-friendly and often use easily available resources. They reflect the cultural wisdom of different regions and continue to play an important role in many households, especially in rural areas. Learning about these methods helps us understand their value in food safety, sustainability and cultural heritage.

This lesson will introduce you to the different types of traditional food processing and preservation techniques, their uses, advantages and relevance in modern times.

3.2.1 SUN DRYING (SOLAR DEHYDRATION)

Sun drying, also known as solar dehydration is one of the earliest and most widely adopted traditional methods of food preservation. This process involves exposing food to natural sunlight over an extended period, allowing gradual moisture removal through evaporation. The central mechanism of preservation lies in reducing the water activity of food, thereby inhibiting microbial growth and slowing down enzymatic reactions. Particularly in warm, sunny climates, this method has been a reliable, energy-free technique to prolong shelf life and minimize spoilage.

Historical and Cultural Significance

The practice of sun drying dates back thousands of years and holds deep cultural roots in several regions across the globe. It has been an indispensable method in early agricultural societies for preserving seasonal abundance. In India, Africa, Southeast Asia and the Middle East, sun drying continues to be an essential part of rural life, enabling families to store food for non-harvest months. Its simplicity, sustainability and adaptability to various food types make it a cornerstone of indigenous food systems.

Solar Dehydration

Foods Commonly Dried

A wide variety of foods are traditionally preserved through sun drying. Cereal grains like rice, wheat, sorghum and millets are dried post-harvest to prevent microbial deterioration. Pulses including lentils, chickpeas and green gram are sun dried to enhance storage life. Fruits such as mangoes, bananas, grapes, apricots and figs are often sliced before drying. Leafy and non-leafy vegetables like spinach, okra, brinjal and tomatoes are dried extensively in rural households. Additionally, spices (e.g., turmeric, chilies, coriander) and even animal-based products like fish and meat are preserved using this method, especially in coastal and tribal communities.

Processing and Drying Procedure

The process typically begins with the careful selection and cleaning of raw materials. Food items may be peeled, sliced, or blanched to improve drying rate and prevent discoloration. In some cases, mild chemical treatments such as dipping in potassium metabisulfite are used to protect against microbial spoilage and to retain color, particularly in fruits. Once prepared, the food is spread in thin layers on clean surfaces like plastic sheets, jute mats, or raised wire mesh trays. Regular turning ensures even exposure to sunlight. During the night or rainy weather, food is covered or brought indoors to prevent rehydration and contamination.

Drying

Scientific Rationale

The effectiveness of sun drying lies in its ability to lower the moisture content of food to a level where microbial growth is drastically slowed or completely inhibited. The process not only inhibits spoilage organisms but also suppresses enzymatic activity that can lead to quality degradation. Ultraviolet rays from sunlight may also offer limited antimicrobial effects. While sun drying does not sterilize food, it makes it significantly more stable under ambient conditions. The final moisture content depends on the type of food and the intensity and duration of drying.

Nutritional Effects

Although sun drying retains many macronutrients and minerals, it may result in a loss of some heat- and light-sensitive micronutrients. Vitamin C, in particular, is highly susceptible to degradation during extended sun exposure. Thiamine and riboflavin, both B-complex vitamins, may also be partially destroyed. However, most of the protein, carbohydrates, fibre and mineral content remain intact, making sun-dried foods nutritionally valuable, especially in off-season periods when fresh produce is scarce.

Benefits of Sun Drying

One of the greatest advantages of sun drying is its minimal resource requirement. It does not require fuel, electricity, or expensive infrastructure, making it ideal for rural and low-income settings. It is environmentally friendly, economically viable, and suitable for small-scale and household use. Sun drying also enables communities to reduce post-harvest losses, maintain food security and generate income through the sale of preserved goods. The method supports local knowledge systems and promotes self-reliance in food preservation.

Drawbacks and Limitations

Despite its advantages, sun drying has notable limitations. It is heavily dependent on weather conditions and cannot be practiced effectively during rainy or highly humid periods. Open drying surfaces expose food to dust, insects, rodents and environmental pollutants, raising food safety concerns. Inadequate drying or uneven moisture removal can lead to mold growth or spoilage. Additionally, nutrient losses and contamination risks must be carefully managed through good handling practices and regular monitoring.

Technological Enhancements

To overcome some of the challenges associated with traditional sun drying, improved systems such as solar cabinet dryers and tunnel dryers have been introduced. These devices provide enclosed, ventilated spaces where solar heat is more efficiently captured and retained, reducing drying time and contamination. In hybrid systems, solar heat may be supplemented with biomass or electric energy, ensuring uninterrupted drying even during cloudy weather. Such adaptations enhance product quality, hygiene and reliability without undermining the traditional nature of the technique.

3.2.2 SMOKING

Smoking is a time-honoured method of food preservation that integrates the effects of mild heat, partial dehydration and the chemical action of smoke compounds to extend the shelf life of perishable foods. By subjecting food to smoke generated from burning selected woods or plant materials, this process not only inhibits microbial activity but also imparts a distinct flavour, colour and aroma. Smoking is predominantly used for meat and fish products, but its application has extended to other food categories over time. It is both a functional and flavor-enhancing preservation method still widely practiced across traditional and modern food systems.

Smoking

Cultural and Historical Background

The origins of smoking as a preservation method can be traced to early human civilizations that discovered that exposure to smoke helped meat and fish last longer. Before the invention of refrigeration, smoking provided a critical solution for preserving food for long journeys, winters and lean seasons. In many cultures, smoking evolved from a mere preservation strategy to a culinary tradition. Indigenous communities in North America, Scandinavia, Africa and Southeast Asia have used smoking not only to preserve surplus food but also to produce regionally distinct, flavourful delicacies that remain integral to local diets.

Scientific Principles and Preservation Mechanism

The preservation efficacy of smoking is based on several complementary mechanisms. The mild heat generated during smoking leads to the evaporation of surface moisture, lowering water activity and discouraging microbial proliferation. In parallel, the smoke contains chemical constituents such as phenols, organic acids, aldehydes and alcohols, which possess antimicrobial and antioxidant properties. These compounds create a protective layer on the food's surface, inhibiting bacterial and fungal growth. In fatty foods, smoke antioxidants delay oxidative rancidity, further prolonging shelf life. The combined effects of moisture reduction, chemical inhibition and partial cooking (in hot smoking) make smoking a powerful preservation method.

Types of Smoking Methods

There are two principal forms of traditional smoking: hot smoking and cold smoking.

Hot smoking is performed at temperatures ranging from 60°C to 80°C, during which the food is both cooked and preserved. This method ensures microbial safety and produces ready-to-eat items such as smoked fish, sausages, or poultry.

Cold smoking is carried out at lower temperatures, typically below 30°C, and does not cook the food. It is primarily used to enhance flavor and is usually combined with other preservation techniques like salting or drying. Cold-smoked foods, such as some types of ham and salmon, require further cooking or curing before safe consumption.

Smoked Meat

Foods Commonly Subjected to Smoking

Traditionally, smoking is widely employed for preserving fish (e.g., salmon, sardines, mackerel), meats (pork, beef, game) and poultry. In several cultures, smoked meat forms an essential component of household diets, especially in regions without refrigeration. In addition to animal products, some dairy products like cheese, certain vegetables, spices (e.g., chilies and garlic), and fermented items are also occasionally smoked for either preservation or flavouring purposes. The specific wood used in smoking oak, hickory, mesquite, or fruitwood can influence the aroma, taste and chemical composition of the smoke, thus affecting the final product's quality.

Step-by-Step Process

Smoking typically begins with the preliminary treatment of the food. This may involve cleaning, salting (dry or wet brining), and air-drying to ensure partial dehydration and surface sanitation. The food is then placed in a smokehouse, smoke pit, or chamber, where it is hung or laid on racks above a slow, smouldering fire. The combustion process must be controlled to ensure the wood produces smoke rather than open flame. Throughout the smoking process which may range from several hours to several days depending on the method the food is regularly monitored for uniform exposure and to avoid over-smoking or burning. Once the process is complete, the product is cooled and packaged under hygienic conditions to prevent recontamination.

Chemical and Microbial Impact

Smoke contains a diverse range of bioactive compounds, including phenolic compounds (which act as antimicrobials and antioxidants), formaldehyde (a protein denaturant), acetic acid (a pH reducer), and carbonyls (which contribute to aroma). These compounds penetrate the surface of the food, creating an environment that is hostile to spoilage organisms and oxidative processes. The cumulative action of heat, smoke chemicals and dehydration reduce microbial load significantly and helps maintain the product's safety and shelf life under ambient conditions. However, the generation of certain compounds, like polycyclic aromatic hydrocarbons (PAHs), which are potentially carcinogenic, must be controlled by maintaining appropriate temperatures and using clean-burning wood.

Nutritional and Sensory Considerations

Smoking has minimal effect on the macronutrient profile of food. Proteins and fats remain largely intact, although there may be minor losses of heat-sensitive vitamins, particularly thiamine (vitamin B1). However, smoking significantly enhances sensory attributes such as flavour, colour and aroma, increasing consumer acceptability and product value. The characteristic smoky flavor is especially prized in culinary contexts and is often a major reason why smoked foods are consumed, beyond their extended shelf life.

Advantages of Smoking

Smoking is a practical and sustainable preservation method that requires relatively low investment. It is accessible in rural settings and does not rely on electricity or refrigeration. This method effectively increases shelf life, adds market value through enhanced flavour and allows for preservation of protein-rich foods in resource-limited areas. Moreover, smoking can be easily combined with other traditional methods such as salting and drying to provide a multi-barrier approach to preservation.

Limitations and Challenges

Despite its advantages, traditional smoking has certain limitations. The process is time-intensive and requires constant monitoring to ensure safety and consistency. Poorly regulated smoke exposure can result in under-processing, leading to microbial risk, or over-processing, which may create bitter flavours and potentially harmful compounds such as PAHs. In traditional settings, hygiene can be a concern due to open environments and inadequate control of pests or contaminants. Furthermore, excessive intake of smoked foods may pose health risks due to high salt content or long-term exposure to smoke residues.

Technological Improvements

Modern adaptations of traditional smoking include enclosed smokehouses and mechanical smoking systems that allow for better control of temperature, humidity and smoke density. These systems reduce contamination risk and prevent the formation of toxic compounds. The use of purified liquid smoke or smoke condensates in industrial processing is another technique that mimics smoked flavor without direct exposure to combustion products. For small-scale or artisanal settings, low-cost modifications such as filtered smoke chambers and improved airflow systems can improve hygiene and product safety while preserving the authenticity of traditional smoking practices.

3.2.3 FERMENTATION

Fermentation is a traditional, biologically driven method of food processing and preservation that relies on the metabolic activities of microorganisms such as bacteria, yeasts and moulds. Through this process, these microbes convert complex organic compounds particularly carbohydrates into simpler substances like organic acids, gases and alcohol. The resulting environment becomes unsuitable for the growth of spoilage-causing microorganisms, thereby extending the shelf life of food. Beyond preservation, fermentation plays a key role in enhancing the nutritional, functional and sensory qualities of foods.

Fermentation

Historical and Cultural Context

The practice of fermentation is deeply rooted in ancient civilizations and is found in nearly every traditional food culture. It originated as a spontaneous natural process and evolved over time into a deliberate and sophisticated method. From ancient Egypt's beer brewing and the yogurt traditions of Central Asia, to India's fermented rice-lentil batters and East Asia's soybean products, fermentation has long been a critical survival and culinary strategy. It remains deeply embedded in cultural rituals, seasonal food practices and local knowledge systems.

Scientific Mechanism and Microbial Activity

The core of the fermentation process lies in the microbial breakdown of sugars under anaerobic or semi-anaerobic conditions. These microorganisms produce metabolic by-products such as lactic acid, acetic acid, ethanol and carbon dioxide that significantly reduce pH and oxygen levels in the food environment. This altered biochemical landscape suppresses spoilage and pathogenic organisms while promoting the growth of beneficial microbes. In traditional food processing, spontaneous fermentation is common, relying on naturally occurring microflora from ingredients, utensils, or the surrounding environment.

Major Types of Fermentation

Fermentation methods can be categorized based on the dominant microbial group and the end-products formed:

Lactic Acid Fermentation:

Conducted by lactic acid bacteria (LAB), this process is typical in products like yogurt, curd, idly, dosa batter, fermented vegetables and cereal gruels. The lactic acid produced lowers the pH and acts as a natural preservative.

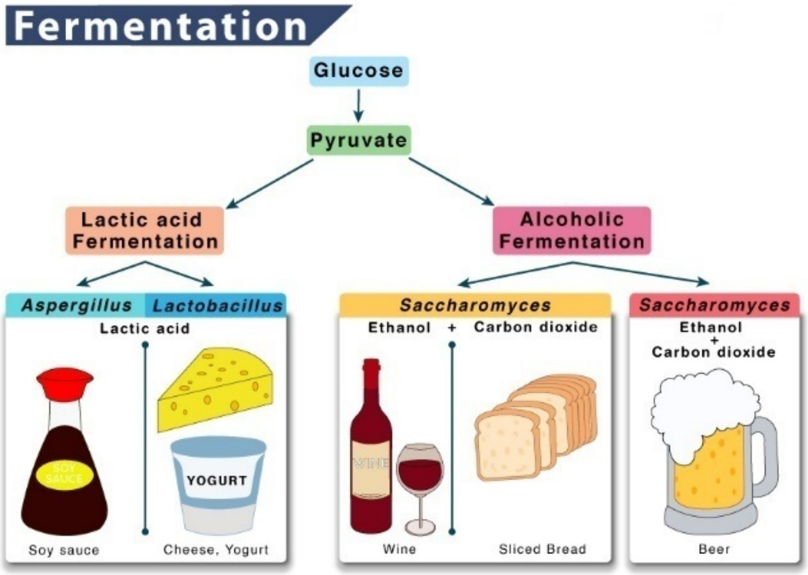
Alcoholic Fermentation:

Driven by yeasts such as *Saccharomyces cerevisiae*, this process converts sugars into ethanol and carbon dioxide. It is fundamental to traditional alcoholic beverages like toddy, millet beer and rice wine.

Acetic Acid Fermentation: Ethanol, produced during alcoholic fermentation, is oxidized to acetic acid by Acetobacter species. This process is used in vinegar production and adds preservative and flavor-enhancing properties.

Alkaline Fermentation: Carried out by Bacillus species and certain fungi, this process involves the production of ammonia and other alkaline compounds, common in fermented legumes and fish in Southeast Asian and African food systems.

Each type of fermentation contributes distinct flavor profiles, nutritional benefits and microbial communities to the final product.



Fermentation

Traditional Examples of Fermented Foods

A diverse range of fermented foods are integral to global traditional diets. In India, common examples include curd, buttermilk, idly, dosa, kanji, fermented pickles and handia (a rice-based beverage). In Africa, fermented cereal pastes and porridges are widely consumed. East Asian cultures are renowned for fermented soybean products such as miso, tempeh, soy sauce and natto. Europe and the Middle East have traditions of fermented dairy (kefir, cheese), bread (sourdough), and vegetables (sauerkraut, olives). These products offer both preservation and culinary enrichment.

Nutritional Improvements

Fermentation significantly enhances food's nutritional quality by improving digestibility and increasing the availability of nutrients. During fermentation, complex compounds such as starches and proteins are broken down into simpler, more absorbable forms. Anti-nutritional factors like phytates and tannins are degraded, thereby enhancing mineral bioavailability (especially iron, calcium and zinc). Additionally, certain microorganisms synthesize B-complex vitamins, including folate, riboflavin and sometimes B12, depending on the strain and substrate used. Fermented foods also introduce live microbial cultures that support gastrointestinal health.

Food Safety and Microbial Protection

A primary advantage of fermentation lies in its ability to create a microbiologically stable product. The reduction in pH, oxygen levels and the production of antimicrobial substances (e.g., bacteriocins, alcohols, organic acids) collectively inhibit the proliferation of harmful microorganisms. Nevertheless, the success of traditional fermentation depends on maintaining appropriate environmental conditions such as temperature, moisture and salt concentration. If these parameters are not well regulated, undesirable or pathogenic microbes may dominate, leading to spoilage or foodborne illness.

Food Safety and Microbial Protection

Sensory Enhancement and Functional Attributes

Fermentation markedly alters and enhances the sensory characteristics of food. It creates a range of textures, sourness, carbonation and umami flavours that are highly desirable and culturally significant. In addition to improved palatability, fermented foods also offer functional health benefits. These include probiotic activity, immunomodulatory effects, improved gut microbiota and anti-inflammatory properties. Some fermented products have been studied for their role in managing conditions like irritable bowel syndrome, lactose intolerance and metabolic syndrome.

Benefits of Fermentation

Fermentation is a low-input, sustainable technique ideal for rural and resource-limited settings. It does not require electricity or advanced machinery and utilizes naturally occurring organisms and local raw materials. It enhances food security by converting perishable crops into stable, storable products. It also supports dietary diversity, income generation through artisanal products and environmental sustainability by reducing waste and post-harvest losses. Culturally, it preserves culinary traditions and local knowledge systems that are crucial for community identity.

Challenges and Limitations

Despite its many benefits, traditional fermentation methods can present certain challenges. In spontaneous fermentations, inconsistency in quality, flavor, or safety may arise due to variations in microbial communities and environmental factors. Poor hygiene or insufficient fermentation time can result in contamination or the production of harmful substances such as biogenic amines. Certain fermented foods may also have high salt content, posing risks for hypertensive individuals. Therefore, traditional fermentation requires careful handling, understanding of microbial ecology and application of food safety principles.

Advances in Fermentation Technology

Modern science has significantly improved the safety and reliability of traditional fermentation. The use of standardized starter cultures ensures consistency in flavour, safety and nutritional quality. Advances in microbiological analysis, pH monitoring and controlled fermentation environments have enabled better regulation of the process. Additionally, fermentation is being explored in functional food development, with a focus on enhancing probiotic content, enriching micronutrients and developing novel health-promoting foods. Integration of traditional knowledge with modern biotechnology has given rise to community-based fermentation models that are both culturally relevant and scientifically sound.

3.2.4 PICKLING

Pickling is a traditional and time-tested method of food preservation that involves the use of acidic, saline, or oily environments to prevent the growth of spoilage-causing microorganisms. By altering the chemical environment around the food either by lowering the pH, reducing water activity, or excluding oxygen pickling extends shelf life while enhancing flavour, colour and texture. This method remains a vital part of food culture in many regions, especially where seasonal food preservation is necessary.

Pickling

Historical and Cultural Significance

Pickling has been practiced for thousands of years across various civilizations, serving both practical and culinary purposes. In ancient societies such as those of Mesopotamia, Egypt, India and China, pickling was essential for storing perishable foods before the advent of refrigeration. In India, pickling is not just a preservation technique but a cultural tradition, with unique recipes passed down through generations. Different states and communities have developed their own characteristic pickles using locally available ingredients, reflecting both biodiversity and culinary heritage.

Scientific Principles and Mechanism

The effectiveness of pickling as a preservation method lies in its ability to create conditions that inhibit microbial proliferation. In acid pickling, the addition of acetic acid (usually from vinegar) or citric acid reduces the pH of the food environment to levels that most pathogens cannot tolerate. In salt-based pickling, osmotic pressure draws water out of both the food and microbial cells, reducing water activity and halting microbial metabolism. Oil-based pickles work by forming a barrier that prevents oxygen exposure, thereby suppressing the growth of aerobic microorganisms. In some cases, fermentation naturally produces lactic acid, further enhancing preservation.

Major Types of Pickling

Traditional pickling practices can be broadly categorized as follows:

Acidic Pickling: This method uses vinegar or lemon juice to acidify the food. It is common in preserving cucumbers, onions, green chilies and mixed vegetables.

Salt Brine (Fermentation-Based) Pickling: In this method, the food is immersed in a saline solution and naturally occurring lactic acid bacteria ferment sugars in the food to produce lactic acid. This type is observed in traditional preparations like sauerkraut, kimchi and certain Indian vegetable pickles.

Oil-Based Pickling: Predominantly practiced in South Asian households, oil pickling uses edible oils such as mustard or sesame oil to create an oxygen-restricted environment. Ingredients are often pre-salted and mixed with aromatic spices before being preserved under a thick layer of oil.

Ingredients and Functional Additives

The success of pickling lies not only in the primary preservation agents salt, acid, or oil but also in the judicious use of flavor-enhancing and antimicrobial spices. Commonly used ingredients include:

- Salt, for drawing out moisture and reducing microbial activity.
- Acids, such as vinegar or citrus juice, to lower the pH and preserve food.
- Oils, to exclude air and add distinctive flavours.
- Spices, such as mustard seeds, turmeric, fenugreek, asafoetida, garlic and red chili, which possess natural antimicrobial and antioxidant properties.

These components work synergistically to preserve the food while enhancing its culinary appeal.

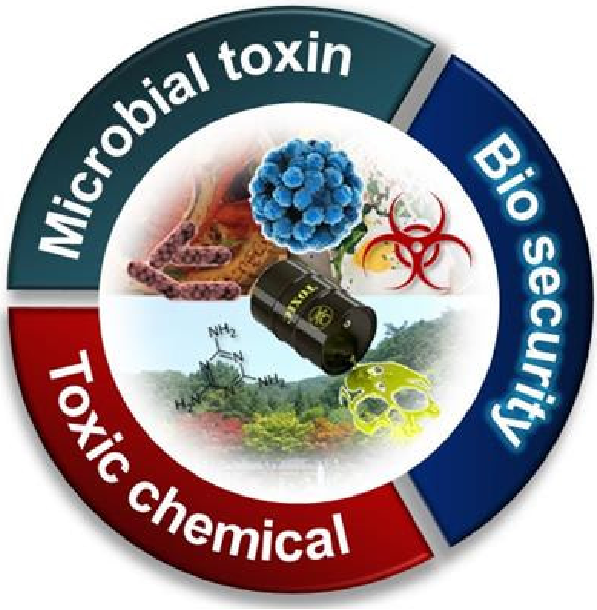
The Pickling Process

The pickling process begins with the thorough cleaning and preparation of the raw ingredients. Depending on the method, the food may be sun-dried, partially cooked, salted, or cut into specific shapes. In salt-based or fermentation pickling, the food is immersed in brine and kept in airtight containers to encourage natural lactic acid fermentation. In vinegar-based pickling, the food is submerged in a vinegar-spice solution and sealed for maturation. Oil pickling involves marinating pre-salted ingredients with ground spices and submerging them in oil. The pickles are typically allowed to mature for days or weeks to develop depth of flavor.

Proper hygiene, use of clean utensils and sterilized jars are essential to ensure microbial safety and prevent contamination during the pickling process. Many traditional methods also incorporate sun exposure to promote fermentation and flavor development.

Microbial and Biochemical Aspects

Pickling suppresses the growth of harmful bacteria and fungi through reduced water activity, lowered pH and limited oxygen availability. Acidic and saline environments are particularly effective in inhibiting the growth of foodborne pathogens such as *Salmonella*, *E. coli* and *Clostridium botulinum*. In naturally fermented pickles, beneficial lactic acid bacteria dominate, contributing to both safety and probiotic effects. However, poor fermentation control or inadequate sanitation can lead to the growth of spoilage organisms or mould, resulting in spoilage or potential health risks.



Microbial and Biochemical Aspects

Nutritional and Sensory Effects

Pickled foods retain most of their macronutrients, though there may be some loss of heat-sensitive vitamins such as vitamin C during preparation. In fermentation-based pickles, the microbial action can enhance nutritional quality by improving the bioavailability of minerals and synthesizing certain B-vitamins. Additionally, probiotic strains found in fermented pickles contribute to gut health and may improve digestion and immune function.

From a sensory perspective, pickled foods are prized for their tangy, spicy and complex flavour profiles. The interplay of salt, acid, oil and spices makes pickles a flavourful accompaniment to meals and a natural appetite stimulant.

Advantages of Pickling

- Pickling offers a number of distinct advantages:
- It enables long-term preservation without refrigeration.
- It enhances the organoleptic properties of food, including flavor, aroma and appearance.
- It requires minimal technological input and is feasible in domestic and rural settings.
- It allows for the use of seasonal produce, reducing food waste.
- In the case of fermentation-based pickles, it introduces beneficial microbial flora.

Because of these benefits, pickling remains a preferred preservation method in households and cottage industries.

Limitations and Precautions

Despite its utility, pickling also has certain drawbacks. Foods preserved with large quantities of salt or acid may not be suitable for individuals with hypertension, kidney disease, or gastrointestinal disorders. Improper ratios of salt, acid, or oil and failure to maintain hygienic conditions during preparation or storage can lead to microbial contamination. Additionally, prolonged exposure to metal containers may result in chemical reactions, so food-grade plastic or glass containers are preferable. Therefore, careful attention to process control and storage conditions is essential for safe consumption.

Technological Developments

Contemporary advances in food technology have improved traditional pickling practices. Commercial pickling industries now employ pasteurization, quality control measures, vacuum sealing and controlled fermentation environments to produce pickles with extended shelf life and consistent quality. Research is being conducted on developing low-sodium and probiotic-enriched pickles for health-conscious consumers. Innovations such as solar dryers and food-safe packaging have also supported the hygienic and sustainable production of pickled foods in rural areas.

3.2.5 SALTING (CURING)

Salting, often referred to as curing, is one of the most ancient and widely utilized traditional techniques for food preservation. It operates by extracting moisture from food materials through the application of salt, thus significantly lowering the water activity (a_aw) necessary for microbial survival and enzymatic activity. By creating a hostile environment for spoilage organisms, salting ensures microbial inhibition, extending shelf life and maintaining food safety.

Curing

Historical Background and Cultural Importance

The practice of using salt to preserve food predates written history and has played a critical role in food security across civilizations. From Egyptian salted fish and meats used in burial rituals to salted hams in Roman and medieval European societies, this technique has had both practical and ritualistic significance. In coastal communities, especially in countries like India, Indonesia and Portugal, salting is deeply ingrained in local food culture and remains a vital method for preserving seafood and meats without modern refrigeration.

Scientific Basis and Mode of Preservation

The core principle behind salting lies in osmosis. When salt is applied to food, it draws out water from the tissues and from microbial cells by creating a hypertonic environment. This removal of free water drastically reduces microbial activity. Moreover, salt interferes with microbial enzyme systems and cellular metabolism, leading to protein denaturation and eventual cell death. The lowered water activity and osmotic stress also hinder the activity of degradative enzymes within the food itself, thus slowing spoilage.

Salting Techniques

Traditional salting practices can be broadly categorized into the following methods:

Dry Salting: Salt is directly rubbed or layered onto the food surface. This method is suitable for items like fish, meat cuts and some vegetables. The salt gradually penetrates the tissue over time, drawing moisture out.

Wet Salting (Brining): Food is immersed in a solution of water saturated with salt. Brining allows for even salt distribution and is often used for meats and vegetables that are to be fermented or later cooked.

Advanced Curing (Optional Additives): In some traditional and semi-modern systems, salt may be combined with sugar, spices, or preservatives such as sodium nitrite to enhance flavour, colour and safety especially in meat preservation.

Wet Salting

Common Foods Preserved by Salting

Salting is particularly valuable in areas with high ambient temperatures and limited access to refrigeration. Common examples of salted foods include:

Marine Fish: Varieties like mackerel, anchovy and sardine are extensively salted and sun-dried in coastal India, Sri Lanka and Southeast Asia.

Meat: Cuts of beef, pork and lamb are cured for later smoking, drying, or direct consumption as jerky or sausages in both Western and Asian culinary traditions.

Vegetables: Leafy greens, radishes and gourds are sometimes salted and sun-dried or fermented in traditional cuisines, especially during off-season periods.

Nutritional and Biochemical Impact

The macronutrient content (protein, fat) of salted foods remains largely stable. However, there may be some loss of water-soluble vitamins particularly B-complex vitamins due to leaching during brining or processing. On the other hand, in plant-based salted products undergoing fermentation, the availability of certain nutrients may increase as antinutritional factors like phytates are broken down. Nevertheless, the most significant nutritional concern lies in the elevated sodium content, which must be managed in populations at risk for hypertension or cardiovascular diseases.

Microbial Safety Considerations

Salting effectively prevents the proliferation of most spoilage bacteria and fungi by reducing water activity to sub-inhibitory levels. It offers protection against major foodborne pathogens such as *Clostridium botulinum*, *Listeria monocytogenes*, and *Salmonella spp*. Salt-tolerant microorganisms, including halophilic bacteria or moulds, may survive but typically do not cause spoilage under correctly salted conditions. However, failure to apply sufficient salt or poor storage conditions can lead to microbial contamination or toxin production, especially in anaerobic settings.

Sensory and Culinary Attributes

Cured foods often develop distinct sensory characteristics, including enhanced umami flavour, firmer texture and deepened colour. Salted fish, for example, gains a dense texture and characteristic aroma, while meats acquire a chewy consistency and rich taste. These properties are not only acceptable but often culturally desirable in many culinary traditions. In fact, salted ingredients are frequently used to flavor other dishes or as condiments, contributing depth and complexity to meals.

Advantages of Salting

Salting offers several practical and cultural benefits:

- It is highly effective for long-term preservation without electricity.
- It enhances taste, texture and colour, making food more appealing.
- It is inexpensive and accessible, particularly in rural and resource-poor areas.
- It reduces post-harvest losses of perishable products.
- It supports preservation of seasonal produce for use throughout the year.

These advantages make salting an enduringly relevant technique, especially in artisanal and domestic food systems.

Limitations and Health Risks

Despite its benefits, excessive salt intake has well-documented health implications, particularly for individuals with hypertension, heart disease, or renal dysfunction. Additionally, traditional salting practices may involve inconsistent salt concentrations, leading to under-curing or spoilage. If dried under unhygienic or humid conditions, salted products may become susceptible to fungal contamination. Therefore, food-grade salt, clean handling and appropriate drying or storage methods are essential for ensuring product safety.

Modern Innovations and Trends

In recent years, salting techniques have been refined to improve both health and safety outcomes. Partial substitution of sodium chloride with potassium chloride or calcium salts is being explored to reduce sodium content. Vacuum-sealing, refrigeration and the addition of natural antimicrobial agents (such as garlic or vinegar) have been integrated into traditional systems. Scientific advances also allow for better monitoring of water activity and microbial load, especially in commercial curing units. These innovations help adapt traditional methods to modern nutritional and food safety standards.

3.2.6 UNDERGROUND STORAGE (ROOT CELLARING AND PIT STORAGE)

Underground storage, encompassing techniques such as root cellaring and pit storage, is a traditional method of preserving food that utilizes the naturally cool, stable environment of the earth. This approach minimizes reliance on energy-based refrigeration systems by maintaining optimal temperature and humidity conditions that slow down enzymatic activity and microbial spoilage. As a result, it extends the shelf life of a variety of fresh agricultural commodities in a cost-effective and sustainable manner.

Underground Storage

Historical and Cultural Significance

The use of subterranean storage methods dates back thousands of years and has been integral to food preservation practices in both temperate and tropical regions. In many cultures, especially those with seasonal harvest cycles or harsh climatic conditions, underground storage was essential for maintaining a continuous food supply. Root cellars were commonly built in Europe and North America to store root vegetables and fruits through the winter months. In South Asia and parts of Africa, pit storage methods have been adapted for storing cereals, pulses and tubers during periods of abundance.

Scientific Principles and Function

The effectiveness of underground storage relies on the earth's capacity to provide thermal insulation. Subsurface temperatures are relatively stable throughout the year, remaining cooler than the ambient air in summer and warmer in winter. This stability helps inhibit microbial growth, delays spoilage and reduces moisture loss from stored produce. Additionally, the absence of light in underground environments helps prevent photodegradation and sprouting in light-sensitive crops like potatoes and onions.

Traditional Storage Structures

Several forms of underground storage have evolved based on geographical and climatic conditions:

Root Cellars: These are partially or fully buried rooms, traditionally built with stone, mud, or wood, and often integrated into the foundations of homes. They are designed with ventilation systems to regulate humidity and airflow and are primarily used to store root vegetables and hardy fruits.

Pit Storage: Common in Indian and African agricultural systems, this involves excavating pits in the ground, which are then lined with materials like straw, clay, or ash to prevent moisture ingress. Food items are stored in containers or sacks and covered with soil, leaves, or cow dung to provide insulation and protection from pests.

Underground Bins or Silos: These are specifically designed for the bulk storage of grains and pulses. Often constructed with mud bricks or concrete and equipped with thatched or metallic lids, they provide protection from rodents, insects, and humidity.

Zeer Pot Coolers: A type of evaporative cooling system, this method involves placing a smaller clay pot inside a larger one, with wet sand packed in between. It is particularly useful in arid regions for preserving vegetables and dairy products without the need for electricity.

Zeer Pot Coolers

Food Commodities Suitable for Underground Storage

A wide range of perishable food items can be stored underground depending on the method and environment:

- Root and tuber crops such as carrots, potatoes, sweet potatoes and yams.
- Bulbs like onions and garlic.
- Hardy fruits such as apples, pomegranates and pears.
- Cereals and pulses stored in pit silos or underground bins in sealed containers.

These commodities benefit from the cool, dark and stable conditions that inhibit sprouting, respiration and microbial degradation.

Microbial and Pest Management

While underground storage generally limits microbial activity due to its low temperature and reduced oxygen exposure, it is not without risk. Excess moisture or poor ventilation can foster mould and bacterial contamination. Traditional pest control measures such as lining pits with ash, neem leaves, or cow dung are used to deter insects and rodents. In grain storage, natural fumigants like dried chilies or camphor may also be employed to enhance biosecurity.

Nutritional Considerations

Because underground storage does not involve heat or chemical treatment, it is generally effective in preserving the nutritional quality of food. Micronutrients such as vitamin C, B-complex vitamins and antioxidants are better retained compared to heat-based preservation methods. However, nutritional degradation may occur if the produce begins to sprout or ferment due to excessive humidity or improper sealing. With proper maintenance, underground storage supports nutrient-dense, fresh food availability during lean seasons.

Design, Maintenance and Operational Guidelines

For underground storage systems to function optimally, several design and maintenance considerations must be addressed:

Site Selection: Storage pits or cellars should be located in elevated, well-drained areas to prevent water logging or seepage.

Construction Materials: The use of breathable but insulating materials like straw, mud, or terracotta helps regulate temperature and moisture.

Ventilation: Adequate airflow is critical, especially in root cellars, to prevent condensation and mould growth.

Moisture Control: Pits must be well-lined and sealed to limit exposure to groundwater and rainfall.

Sanitation: Containers, walls and tools should be cleaned regularly. Only healthy, undamaged produce should be stored to avoid the spread of rot.

Benefits of Underground Storage

This preservation method offers a variety of advantages, particularly in traditional or resource-constrained settings:

- Low-cost and energy-free operation.
- Reduction in post-harvest losses, particularly in rural areas.
- Retention of nutritional and sensory quality without the use of additives or heat.
- Accessibility, as it relies on locally available materials and indigenous knowledge.
- Sustainability, by minimizing environmental impact and promoting food security during off-seasons.

These benefits make underground storage especially relevant in climate-resilient agricultural systems and low-income communities.

Challenges and Limitations

Despite its advantages, underground storage has some limitations that must be acknowledged:

Suitability: Not all food items are appropriate for underground preservation.

Pest and mould control: If not managed properly, pits can become breeding grounds for pests or fungi.

Labour-intensive upkeep: Regular monitoring and cleaning are required to maintain hygiene and quality.

Climatic Constraints: High groundwater tables, poor drainage, or excessive rainfall can compromise storage safety.

Thus, careful design, selection of appropriate produce and monitoring are crucial for effective long-term storage.

Innovations and Modern Integration

Modern adaptations of underground storage build upon traditional techniques with improved materials and structural design. For instance, concrete-lined root cellars with solar ventilation are being promoted in some rural development programs. Improved insulation materials, moisture barriers and aeration systems have enhanced storage reliability. Additionally, the combination of traditional storage with data loggers or sensors for temperature and humidity monitoring has bridged traditional and modern post-harvest technologies.

3.2.7 FERMENTATION

Fermentation is a time-honoured method of food preservation that relies on the controlled action of microorganisms primarily bacteria, yeasts and moulds to bring about desirable biochemical transformations in food substrates. Through the breakdown of carbohydrates into simpler compounds such as organic acids, ethanol and gases, fermentation not only prolongs the shelf life of foods but also enhances their nutritional quality, safety and sensory appeal. This microbial-driven process is central to many traditional diets across the world.

Acetic Acid Fermentation

Cultural and Historical Significance

The use of fermentation in food systems dates back to ancient civilizations. Before the advent of refrigeration or chemical preservation, communities across Asia, Africa, Europe and the Americas developed fermentation techniques as a means of extending food availability beyond harvest seasons. These practices evolved regionally and gave rise to a wide variety of fermented products ranging from dairy, cereal and vegetable-based preparations to alcoholic beverages and meat fermentations. In many traditional cultures, fermented foods carry ritual, medicinal and symbolic value, showcasing the intersection of biological function and cultural identity.

Scientific Mechanism

At the core of fermentation is microbial metabolism, where specific microorganisms convert fermentable sugars into metabolites like lactic acid, ethanol, or acetic acid. These end-products create acidic or anaerobic conditions that hinder the proliferation of spoilage and pathogenic organisms. Moreover, some microbes used in fermentation produce antimicrobial agents such as bacteriocins, further contributing to food safety. The reduction in pH, alteration in redox potential and depletion of available nutrients all contribute to preserving food in a biologically stable form.

Major Types of Traditional Fermentation

Lactic Acid Fermentation involves the conversion of sugars into lactic acid by lactic acid bacteria (LAB) such as Lactobacillus, Leuconostoc and Streptococcus. This is widely used in the production of curd, fermented batters (e.g., idly, dosa) and pickled vegetables.

Alcoholic Fermentation is driven by yeasts like *Saccharomyces cerevisiae*, which convert sugars into ethanol and carbon dioxide. It is used in brewing traditional beverages such as toddy, millet beer and rice wine.

Acetic Acid Fermentation occurs when ethanol is further oxidized into acetic acid by Acetobacter species, forming the basis for vinegar production.

Alkaline Fermentation is practiced in certain cultures where Bacillus species decompose proteins into peptides and ammonia, leading to an increase in pH. This is common in fermented legume products like natto, kinema, or African dawadawa.

Lactic Acid Fermentation

Examples of Traditional Fermented Foods

Traditional fermentation methods have given rise to a wide variety of region-specific products. Dairy-based ferments like curd and buttermilk are staples in Indian households. Cereal-based products such as idly, dosa and appam involve mixed fermentation. Vegetables are fermented to produce pickles, kimchi, or sauerkraut. In coastal regions, fermented fish pastes are used both as condiments and protein sources. Alcoholic beverages derived from palm sap or fermented grains serve both ritualistic and recreational purposes.

Nutritional Advantages

Fermentation enhances food value in multiple ways. It improves the digestibility of complex foods by breaking down macronutrients. Microbial action reduces the levels of antinutritional factors like phytates, thereby increasing mineral bioavailability. Several B-vitamins such as folate, niacin, riboflavin and B12 are either synthesized or retained more effectively in fermented foods. In addition, some fermented products contain probiotics that positively impact gut health, immunity and nutrient absorption.

Microbial Safety

One of the critical benefits of fermentation is its natural antimicrobial action. The acidic or alcoholic environment produced during fermentation restricts the growth of foodborne pathogens. Well-executed lactic acid fermentation can lower pH levels to below 4.5, which is inhospitable to many harmful bacteria. However, uncontrolled fermentation, poor hygiene, or improper storage conditions can result in the growth of undesirable microbes or the accumulation of toxic compounds like biogenic amines, emphasizing the need for proper technique.

Sensory Modifications

Fermentation significantly modifies the sensory characteristics of food. The formation of organic acids, esters and alcohols imparts complex flavours and aromas. Textural changes also occur, often softening fibrous ingredients and creating spongy or creamy consistencies. Fermentation is therefore not only a preservation method but also a culinary tool that enhances the appeal of food through taste, smell and mouthfeel.

Factors Influencing Fermentation

- The quality of fermentation is influenced by several interrelated factors:
- The microbial population, which may be naturally present or introduced via starter cultures.
- Temperature, which governs microbial growth rates and enzymatic activity.
- Salt concentration, especially in vegetable and fish fermentation, where it acts as a selective agent.
- Anaerobic or aerobic conditions, depending on the desired end-products.
- Duration, which must be optimized to ensure safety, proper acidity and flavour development.

- Traditional knowledge systems often rely on observation, experience and environmental cues to manage these factors.

Benefits of Traditional Fermentation

Traditional fermentation methods are eco-friendly, require minimal equipment and add functional value to food. They extend shelf life naturally, reduce dependency on synthetic preservatives and contribute to dietary variety. Fermentation also enhances nutrient quality and can make food more acceptable to individuals with specific health conditions, such as lactose intolerance. The low cost and adaptability of fermentation techniques make them especially valuable in low-resource communities.

Drawbacks and Limitations

While fermentation is generally safe and beneficial, certain limitations exist. Variability in microbial composition may result in inconsistent quality or product failure. Lack of hygiene during the process can introduce contaminants. Over-fermentation may lead to undesired flavours or the accumulation of harmful metabolites. Additionally, modernization has led to the decline of traditional knowledge and practices, posing a risk to the continuity of this heritage technique.

Contemporary Innovations

In recent years, advances in microbiology and food science have revived interest in fermentation. Standardized starter cultures are now used to ensure consistency and safety. Researchers are isolating beneficial microbial strains with probiotic potential for commercial application. Fermented functional foods and beverages are gaining popularity in urban markets. Furthermore, community-based fermentation units are being established to empower rural food systems and preserve traditional knowledge.

3.3 SUMMARY:

Traditional food processing and preservation methods are deeply rooted in cultural heritage and have evolved over generations to maintain food quality, extend shelf life and ensure year-round availability in the absence of modern refrigeration or additives. Techniques such as sun drying, smoking, fermentation, pickling, salting, underground storage and germination/malting utilize natural processes including dehydration, acidification, microbial action and enzymatic transformation to inhibit spoilage and enhance both the safety and nutritional value of foods. These practices not only conserve essential nutrients but also contribute to the unique sensory characteristics and medicinal properties of traditional diets. Although some challenges exist, such as dependency on environmental conditions and hygiene practices, these methods remain highly relevant for sustainable food systems, especially in low-resource settings. When combined with scientific knowledge, traditional processing techniques offer valuable solutions for improving food security, health and dietary diversity.

3.4 TECHNICAL TERMS:

Water activity ($a_a w$), Lactic acid fermentation, Enzymatic hydrolysis, Anaerobic fermentation, Desiccation, Antimicrobial phytochemicals

3.5 SELF ASSESSMENT QUESTIONS:

1) How do traditional preservation methods like drying and fermentation work based on scientific principles?
2) Why is controlling water activity essential for preventing food spoilage?
3) In what ways does fermentation improve both the nutritional quality and safety of foods?
4) How do regional and cultural factors influence traditional food preservation practices?
5) What limitations are commonly encountered in traditional processing methods, and how can they be minimized?
6) How can traditional preservation techniques be effectively combined with modern food science to improve food systems?

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LESSON-4

PRESERVATIVES AND ADDITIVES-CLASSIFICATION, APPLICATIONS, PERMISSIBLE LIMITS AND SAFETY ASPECTS

4.0 OBJECTIVES:

After going through this lesson, students will be able to:

- To understand the classification of food preservatives and additives based on their functional roles in food
- To identify the wide range of applications of preservatives and additives in enhancing shelf life, flavour, texture and appearance of food products.
- To emphasize the importance of permissible limits set by regulatory bodies (like FSSAI, FDA, Codex) to ensure safe consumption.
- To highlight the safety aspects associated with their use, including potential health risks from overuse or misuse.

STRUCTURE:

4.1 INTRODUCTION

In the modern food industry, maintaining the quality, safety and appeal of food products is essential. To achieve this, preservatives and additives are widely used. These substances are added to foods in small quantities to serve specific technological purposes, such as prolonging shelf life, enhancing flavor, improving appearance and maintaining nutritional value.

Preservatives are primarily used to prevent spoilage caused by microbial growth, oxidation and other chemical reactions. They help in extending the shelf life of perishable products, ensuring food safety and reducing food waste.

Food additives, on the other hand, include a broader category of substances that improve the sensory qualities and stability of food. These include colorants, flavor enhancers, emulsifiers, stabilizers, thickeners and more. Additives play a crucial role in the production of consistent, appealing, and nutritious food products suited to modern consumer demands.

The safe and regulated use of preservatives and additives is essential for protecting public health while enabling large-scale food production and distribution. Their application is governed by food safety authorities worldwide to ensure they meet permissible limits and do not pose health risks.

4.2 PRESERVATIVES

Food preservatives are natural or synthetic substances added to food products to prevent spoilage, inhibit the growth of microorganisms (such as bacteria, yeast and molds) and extend the shelf life of the food by maintaining its freshness, taste and appearance.

4.3 CLASSIFICATION OF PRESERVATIVES

1. BASED ON ORIGIN

a. Natural Preservatives

These are substances obtained from natural sources such as plants, animals, or minerals. They have been used for centuries in traditional food preservation.

- Salt helps remove moisture and prevents the growth of bacteria. It is widely used in pickles, meat and fish.
- Sugar acts as a preservative by binding water and preventing microbial growth. It is used in jams, jellies and syrups.
- Vinegar, which contains acetic acid, lowers the pH of food and inhibits bacterial growth. It is commonly used in pickling.
- Lemon juice contains citric acid and is used to preserve the freshness and color of fruits and vegetables.
- Spices like cloves, cinnamon and garlic have natural antimicrobial properties.
- Honey acts as a natural sweetener and preservative, often used in traditional medicine and food preservation.

Natural Preservatives

b. Synthetic (Artificial) Preservatives

These are man-made chemicals developed to enhance food preservation more effectively and consistently. They are used in processed and packaged foods.

- Sodium benzoate is widely used in acidic foods and beverages to prevent the growth of bacteria, yeast and fungi.
- Potassium sorbate is used in cheese, yogurt and dried fruits to inhibit mold and yeast.
- Sulphur dioxide is used in wines and dried fruits to prevent spoilage and discoloration.
- BHA and BHT are synthetic antioxidants that prevent fats and oils from becoming rancid.
- Sodium nitrite and nitrate are used in cured meats to prevent bacterial growth and preserve color.

Synthetic (Artificial) Preservatives

2. BASED ON FUNCTION

a. Antimicrobial Preservatives

These prevent or slow down the growth of microorganisms like bacteria, yeast and mold. They are especially important for foods with high moisture content.

Examples include sodium benzoate, potassium sorbate and nitrites. They are commonly used in fruit juices, cheese, meats and sauces.

b. Antioxidant Preservatives

These prevent oxidation in foods, which can cause changes in colour, flavour and nutritional value. Oxidation is common in fatty foods and oils.

Examples include BHA, BHT, ascorbic acid (vitamin C) and tocopherols (vitamin E). These preservatives are found in snacks, oils and processed foods.

c. Chelating Agents (Sequestrants)

These bind to metal ions that can catalyse oxidation and spoilage reactions. By controlling metal ions, they help extend shelf life.

Common chelating agents include EDTA and citric acid, which are used in soft drinks, canned food and salad dressings.

d. Enzyme Inhibitors

These preservatives work by stopping the activity of natural enzymes in food that cause spoilage or browning. Enzymatic browning can occur in fruits and vegetables when cut or exposed to air.

An example is sulphur dioxide, which is used to prevent browning in dried fruits and potatoes.

3. BASED ON MODE OF ACTION

a. Static Preservatives

These inhibit the growth of microorganisms without killing them. Microorganisms stay inactive.

Example: Sodium benzoate

b. Cidal Preservatives

These kill microorganisms completely and prevent spoilage.

Example: Nitrites used in meat preservation

4. BASED ON PHYSICAL FORM

a. Solid Preservatives: Used in powdered or crystalline form.

Examples: BHA, BHT, Sodium nitrite

b. Liquid Preservatives: Used in liquid solutions, especially in beverages and canned foods.

Examples: Sodium benzoate solution, vinegar, sulphur dioxide gas in solution.

Sodium Benzoate

4.4 APPLICATIONS OF PRESERVATIVES

Food preservatives play a vital role in extending shelf life, preventing spoilage and maintaining food quality and safety. Their applications span across nearly all categories of food products.

1. Preservation of Beverages

Soft drinks, fruit juices, squashes and syrups are prone to microbial growth due to their sugar and water content. Preservatives like sodium benzoate and potassium sorbate are added to inhibit the growth of bacteria and yeasts, especially in acidic drinks.

2. Bakery Products

Bread, cakes, pastries and muffins are prone to mold and bacterial growth due to moisture and warmth. Preservatives like calcium propionate and sorbic acid are used to prevent spoilage and extend shelf life.

3. Dairy Products

Cheese, yogurt, and butter require preservation from mold, yeast and bacterial contamination. Nisin (a natural preservative), sorbic acid and natamycin are commonly used. These helps maintain texture and flavor while ensuring microbial safety.

4. Meat and Poultry Products

Processed meats like sausages, bacon, hot dogs, ham and salami are preserved using sodium nitrite and nitrate. These not only prevent bacterial growth (especially *Clostridium botulinum*) but also maintain the characteristic pink color and flavor.

5. Seafood and Fish Products

Preservatives such as salt, sodium benzoate, and citric acid are used in fish pickles, canned seafood and dried fish to control microbial growth and oxidation. Freezing combined with preservatives helps in the long-term storage of fish.

6. Pickles and Sauces

Pickles contain high salt, vinegar, and sometimes oil. Additional preservatives like sodium benzoate and acetic acid are used to enhance shelf life. Tomato ketchup, chili sauces and soya sauces often contain benzoates and sorbates.

7. Dried Fruits and Nuts

Sulphur dioxide, ascorbic acid and citric acid are used to prevent browning and maintain the color and flavor of dried fruits like raisins, apricots and apples. They also help in avoiding insect infestation and mold.

8. Confectionery and Snacks

Candies, chocolates, chips and snack mixes contain fats and are susceptible to rancidity. BHA (butylated hydroxy anisole) and BHT (butylated hydroxytoluene) are used to delay oxidation and maintain freshness.

9. Canned and Processed Foods

Preservatives are essential in canned vegetables, beans, soups and ready-to-eat meals to prevent spoilage after sealing. Sorbic acid, citric acid, EDTA and ascorbic acid are common preservatives in such products.

10. Frozen Foods

Although freezing itself is a method of preservation, some frozen items like frozen fruits and ready-to-cook meals use preservatives such as citric acid or natural antioxidants to preserve color and prevent freezer burn.

11. Oils and Fats

Edible oils, ghee and butter are prone to oxidative rancidity. Antioxidants like BHA, BHT and tocopherols (Vitamin E) are used to maintain their quality, especially during long-term storage.

12. Health Supplements and Nutraceuticals

Many protein powders, energy bars, vitamin syrups and herbal products use preservatives like sorbates, benzoates and ascorbic acid to keep the product stable and effective over time.

Canned and Processed Foods

4.5 PERMISSIBLE LIMITS OF PRESERVATIVES

1. Sodium Benzoate

- Sodium benzoate is widely used in acidic foods and beverages such as soft drinks, fruit juices and pickles.
- According to food safety authorities, the maximum permissible limit of sodium benzoate in most foods is 0.1% by weight.
- In India (FSSAI), it can be used up to 2 grams per kilogram (0.2%) in certain categories like fruit juices and jams.
- The acceptable daily intake (ADI) set by JECFA is 0 to 5 mg per kg of body weight per day.

2. Potassium Sorbate / Sorbic Acid

- Potassium sorbate is commonly used to prevent mold and yeast growth in bakery products, cheese and beverages.
- The typical limit in food is around 0.1 to 0.2% by weight.
- In India, the FSSAI allows its use up to 2 grams per kilogram in many foods.
- The ADI is set between 0 to 25 mg per kg of body weight per day.

3. Sulphur Dioxide and Sulphites

- These preservatives are used mainly in dried fruits, wines, juices and pickles to prevent browning and microbial growth.
- In dried fruits, the permissible limit can go up to 5 grams per kilogram (0.5%).
- The ADI for sulphur dioxide is 0 to 0.7 mg per kg of body weight per day.
- Sulphites must be declared on food labels if present above 10 parts per million (ppm).

4. Sodium Nitrite and Nitrate

- Used primarily in cured meats to prevent bacterial growth (especially *Clostridium botulinum*) and maintain pink color.
- The permitted level of sodium nitrite in processed meats is usually around 100 to 200 parts per million.
- In India, FSSAI permits sodium nitrite up to 2000 milligrams per kilogram in some processed meat products.
- The ADI for nitrites is 0 to 0.2 mg per kg of body weight per day.

5. BHA (Butylated Hydroxy Anisole)

- This synthetic antioxidant is used to prevent fat and oil oxidation in products like snacks, cereals and chewing gum.

- The maximum permissible concentration is 200 parts per million (ppm), or 0.02%, based on fat content.
- The ADI for BHA is 0 to 0.5 mg per kg of body weight per day.

6. BHT (Butylated Hydroxytoluene)

- Similar to BHA, BHT prevents rancidity in fatty foods.
- The allowed limit is generally around 50 to 100 ppm in food products like oil, chips and breakfast cereals.
- Its ADI is 0 to 0.3 mg per kg of body weight per day.

7. Propionates (Sodium, Calcium Propionate)

- These are used to prevent mold growth in bakery items such as bread and cakes.
- The permissible limit for calcium and sodium propionate is up to 5 grams per kilogram of the product in India and other countries.
- These are considered safe and have no specific ADI defined, as long as they are used within functional need.

8. EDTA (Ethylene Diamine Tetra acetic Acid)

- EDTA is used as a sequestrant in canned foods, beverages and mayonnaise to bind metal ions and enhance stability.
- The FDA permits its use at levels ranging from 25 ppm in beverages to 800 ppm in canned legumes or seafood.

EDTA (Ethylene Diamine Tetra acetic Acid)

Note:

- ➢ These limits vary slightly between countries, and the values mentioned are approximate regulatory thresholds.
- ➢ All food manufacturers must adhere to the limits prescribed by national food safety authorities like FSSAI in India.
- ➢ Preservatives should only be used when necessary and in the minimum effective dose.

- Long-term or excessive consumption above the ADI can pose health risks, particularly in sensitive individuals (e.g., asthmatics, children).

4.6 SAFETY ASPECTS OF PRESERVATIVES

Food preservatives are substances added to food to prevent spoilage, microbial contamination, or undesirable chemical changes. While they are essential for food safety and shelf life, their safety depends on the type, quantity used and individual sensitivity.

1. Regulatory Oversight and Approval

Before any preservative is approved for use, it is rigorously evaluated by food safety authorities such as:

- FSSAI (Food Safety and Standards Authority of India)
- FDA (Food and Drug Administration, USA)
- EFSA (European Food Safety Authority)
- WHO/FAO – JECFA (Joint FAO/WHO Expert Committee on Food Additives)

These organizations assess the toxicological data, carcinogenicity, mutagenicity and metabolic behaviour of each additive. Based on this, they assign an Acceptable Daily Intake (ADI) the amount considered safe to consume daily over a lifetime.

FSSAI (Food Safety and Standards Authority of India)

2. Acceptable Daily Intake (ADI)

- ADI is expressed in milligrams per kilogram of body weight.
- If consumed within this limit, preservatives are considered safe for the general population.
- Exceeding ADI regularly, either through high consumption of preserved foods or accumulation from multiple sources, may increase health risks.

3. Potential Health Concerns

➤ Allergic Reactions and Sensitivities

- Sulphites, benzoates and nitrites may trigger asthma-like symptoms, hives, or skin rashes in sensitive individuals.

- Sodium benzoate, when combined with vitamin C, may form benzene, a carcinogen (though usually in trace amounts).

➤ Hyperactivity in Children

- Studies suggest that artificial preservatives and colorants (especially sodium benzoate) may contribute to hyperactivity and attention-deficit behaviours in some children.

➤ Carcinogenic Concerns

- Nitrites and nitrates, when used in processed meats, can form nitrosamines in the stomach, which are potentially carcinogenic.
- BHA and BHT, though widely used antioxidants, have shown cancer-causing effects in animal studies, but human risk at regulated levels is low.

➤ Disruption of Gut Microbiome

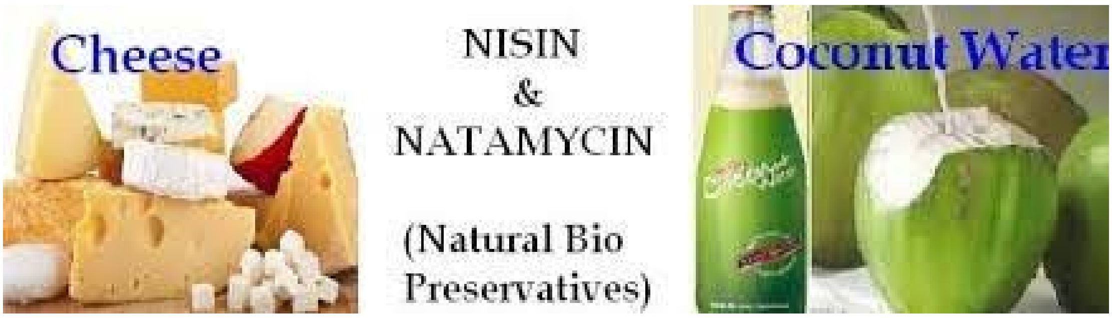
Excessive consumption of antimicrobial preservatives (e.g., sorbic acid) may disturb gut bacteria, which play a crucial role in immunity and digestion.

4. Preservatives Considered Generally Safe

Some preservatives are considered low-risk or safe when used properly, such as:

- Citric acid (found in fruits)
- Ascorbic acid (Vitamin C)
- Tocopherols (Vitamin E)
- Vinegar (Acetic acid) and Salt – used traditionally
- Nisin and natamycin – natural preservatives

These are often used in organic or clean-label foods.



Nisin and natamycin

5. Labelling and Consumer Rights

- Regulations require that all food products:
- List preservatives by name or INS number
- Declare if allergens like sulphites are present above threshold levels (e.g., 10 ppm in India and the US)

6. Safe Use by Manufacturers

- Preservatives must only be used at minimum effective concentrations.
- Their use must not mask spoilage or poor hygiene in manufacturing.
- Food businesses must follow Good Manufacturing Practices (GMP) and ensure compliance with national food laws.

7. Recommendations for Consumers

- Limit frequent intake of highly processed or packaged foods.
- Read food labels for preservative content.
- Choose fresh, homemade, or preservative-free alternatives when possible.
- People with conditions like asthma, allergies, or migraines should be cautious with sulphites, nitrites and benzoates.

4.7 ADDITIVES

Food additives are substances not normally consumed as food itself or used as a typical ingredient of food, but which are intentionally added to food for a technological purpose in its manufacture, processing, preparation, treatment, packing, transport or storage.

4.8 CLASSIFICATION OF ADDITIVES

Food additives are classified based on their functional role in food processing and preservation. These classes help manufacturers choose the right additive for a specific purpose.

Food Additives

1. Preservatives

Preservatives prevent or slow down spoilage caused by microorganisms such as bacteria, molds and yeasts. They help extend shelf life and ensure food safety during storage and transport.

Examples include sodium benzoate, potassium sorbate and sulphur dioxide.

2. Antioxidants

These additives prevent the oxidation of fats and oils, which can cause rancidity, off-flavours and colour changes. Antioxidants maintain freshness and nutritional quality in fatty foods.

Examples include butylated hydroxy anisole (BHA), butylated hydroxytoluene (BHT) and tocopherols (vitamin E).

3. Colouring Agents

Color additives enhance or restore the appearance of food. They can be natural (like carotenoids or beet juice) or synthetic (like tartrazine or brilliant blue). Colours are especially important in candies, drinks and processed foods.

4. Flavouring Agents

These include natural and synthetic substances that give or enhance the flavor and aroma of foods. They are commonly used in snacks, sauces, soups and baked goods.

Examples include vanilla essence, monosodium glutamate (MSG) and citral.

5. Sweeteners

Sweeteners are used to add sweetness to food products, especially in low-calorie or sugar-free foods. Natural sweeteners include stevia and honey, while artificial ones include aspartame and saccharin.

6. Emulsifiers

Emulsifiers help mix two immiscible substances like oil and water and maintain their stable combination in products such as mayonnaise, salad dressings and ice cream.

Common emulsifiers include lecithin and mono- and diglycerides.

7. Stabilizers

Stabilizers maintain the uniform dispersion of ingredients in foods and prevent separation over time. They are used in dairy products, dressings and sauces.

Examples include carrageenan, xanthan gum and guar gum.

8. Thickeners and Gelling Agents

These additives increase the viscosity or thickness of food and are often used in soups, sauces and jelly products.

Examples include starch, pectin and agar.

Thickeners and Gelling Agents

9. Acidity Regulators

These additives control the pH of food, enhancing flavour, preserving quality and preventing spoilage.

Examples include citric acid, lactic acid and sodium bicarbonate.

10. Anti-caking Agents

They prevent powdered foods (like salt, sugar, or spices) from clumping together, ensuring free-flowing texture during packaging and use.

Examples include silicon dioxide and calcium silicate.

11. Humectants

Humectants retain moisture in foods and prevent them from drying out. They are used in baked products, confections and cosmetics.

Examples include glycerol and sorbitol.

12. Bulking Agents

These are used to increase the volume of food without significantly altering its energy content.

Examples include cellulose and maltodextrin.

13. Glazing Agents

These additives provide a shiny appearance or protective coating on the surface of foods like candies or fruits.

Examples include beeswax and shellac.

14. Nutritional Additives

These are added to improve the nutritional value of foods by fortifying them with essential vitamins, minerals, or amino acids.

Examples include iron, folic acid and vitamin D.

Glazing Agents

4.9 APPLICATIONS OF ADDITIVES

Food additives serve multiple purposes in food processing, preservation, appearance and flavour. Below are the key areas where different types of food additives are applied in the food industry:

1. Preservation of Food

One of the oldest and most important uses of additives is to extend the shelf life of food by preventing microbial growth, oxidation and chemical spoilage. Preservatives such as sodium benzoate, sulphur dioxide, and potassium sorbate are widely used in fruit juices, jams, pickles and soft drinks to prevent the growth of bacteria, yeast and molds.

2. Enhancing or Restoring Flavor

Flavouring agents are added to foods to improve taste and aroma, or to restore flavor lost during processing. They include natural flavours like vanilla, lemon oil and herb extracts, as well as synthetic compounds like monosodium glutamate (MSG). These are commonly used in snacks, soups, sauces, baked items and processed meats.

3. Improving Appearance and Color

Color additives are used to make food look more appealing and to restore color lost during processing or storage. Natural colorants like carotenoids, curcumin and anthocyanins are often used in juices, dairy products and confectionery. Synthetic colours are also used in candies, beverages and baked goods.

4. Sweetening Without Sugar

Artificial and natural sweeteners are used in diet foods, diabetic-friendly products and sugar-free items to provide sweetness without the calories or effects of sugar. Examples include aspartame, saccharin, stevia and sorbitol, which are used in soft drinks, chewing gum.

5. Maintaining Texture and Stability

Emulsifiers, stabilizers and thickeners help maintain the consistency, texture and mouthfeel of food. For instance, lecithin keeps chocolate and mayonnaise from separating, while xanthan gum and guar gum stabilize ice creams, sauces and yogurts. These additives prevent separation and enhance the product’s quality during storage.

6. Enhancing Nutritional Value

Some food additives are used for fortification adding nutrients to improve the health benefits of food. Common examples include adding iron to cereals, vitamin D to milk, or iodine to salt. These nutritional additives help prevent deficiencies in the general population.

7. Controlling Acidity or Alkalinity

Acidity regulators are added to maintain or alter the pH level of food, which can improve flavour, texture and microbial safety. For example, citric acid and acetic acid are used in soft drinks, salad dressings, and pickled products to provide a tangy taste and prevent microbial spoilage.

8. Preventing Clumping in Powdered Products

Anti-caking agents are used in powdered and granular food products such as salt, coffee creamer and baking powder to prevent moisture absorption and keep the product free-flowing. Examples include silicon dioxide and calcium silicate.

9. Moisture Retention

Humectants help food retain moisture and stay soft, especially in baked goods and candies. Glycerol and sorbitol are common humectants used in chewing gum, cakes and dried fruits to prevent them from drying out.

10. Providing Shine or Protective Coating

Glazing agents are applied on the surface of food to give it a shiny appearance or to protect it from moisture loss. For example, beeswax is used on fresh fruits and candies to improve appearance and shelf life.

11. Aiding in Food Processing

Some additives help in processing efficiency, such as enzymes, bleaching agents, or firming agents. These are used in flour treatment, canned vegetables and cheese-making to achieve desired food characteristics and reduce production time.

4.10 PERMISSIBLE LIMITS OF ADDITIVES

The use of food additives is strictly controlled and regulated by food safety authorities such as the Food Safety and Standards Authority of India (FSSAI), the U.S. FDA and Codex Alimentarius (WHO/FAO). These authorities determine the maximum amount of an additive that can be safely added to specific food categories based on scientific studies.

This maximum amount is often expressed as: ppm (parts per million), mg/kg (milligrams per kilogram of food), or as a Good Manufacturing Practice (GMP) level (the minimum amount required to achieve the desired effect, not exceeding safety limits).

Good Manufacturing Practice (GMP)

1. Preservatives

- For example, sodium benzoate, a commonly used preservative in fruit juices, soft drinks and pickles, has a limit of about 200–1000 mg/kg, depending on the type of food.
- Similarly, potassium sorbate, used in jams and bakery products, is allowed up to 1000 mg/kg in many food types.
- Sulphur dioxide, used in dried fruits and juices, is usually permitted up to 100 ppm in soft drinks and higher in dried fruits.

2. Artificial Sweeteners

- Additives like aspartame have an acceptable daily intake (ADI) of about 40 mg per kg of body weight. That means a 50 kg person should not consume more than 2000 mg of aspartame in one day.
- Saccharin is allowed in beverages up to around 300–500 mg per litre, depending on local regulations.
- Sucralose may be used up to 300–600 mg per litre in soft drinks and flavoured beverages.

3. Colouring Agents

- For synthetic food colours like tartrazine, sunset yellow and brilliant blue, the maximum limit in foods is usually around 100 mg/kg, depending on the type of food product.
- Natural colours like curcumin or beta-carotene may be used more freely but still have defined limits in processed products.

4. Antioxidants

- Antioxidants such as butylated hydroxy anisole (BHA) and butylated hydroxytoluene (BHT), used in oils, fats and bakery products, are typically allowed in the range of 100–200 mg/kg.
- Exceeding these levels can pose health risks over time, so close monitoring is mandatory.

5. Emulsifiers, Stabilizers and Thickeners

- These are often used under GMP conditions, meaning only the amount needed to achieve the required effect should be used.
- However, for certain types like lecithin, xanthan gum and carrageenan, the general limit is usually below 5000 mg/kg (5 g/kg) in most food applications such as dairy, desserts, or sauces.

6. Flavouring Agents

Most natural flavouring substances like vanillin, menthol, or citral are used under GMP there's typically no fixed upper limit as they are considered safe at low concentrations. However, some synthetic flavourings do have ADIs and their levels are monitored in flavoured products.

Flavouring Agents

7. Acidity Regulators

Acids such as citric acid, malic acid and acetic acid are used widely and are permitted in relatively higher amounts, often up to 3000–5000 mg/kg, depending on the food category. These are generally recognized as safe when used within these limits.

8. Nutritional Additives

Fortification additives like iron, vitamin D, folic acid and iodine also have strict limits to avoid toxicity. For instance, iodine in iodized salt must be between 15 and 30 ppm and folic acid in flour is limited to around 1–3 mg/kg depending on national guidelines.

4.11 SAFETY ASPECTS OF ADDITIVES

Food additives are widely used in the food industry to improve shelf life, flavour, colour and texture. However, their safety is a matter of serious concern. The safety aspects involve toxicological evaluation, regulatory approval, permissible limits and monitoring of adverse effects. Only additives that have been thoroughly tested and proven safe are permitted in food products.

1. **Toxicological Evaluation**

Before a food additive is approved for use, it undergoes rigorous toxicological testing to evaluate its safety. These tests include:

- Acute toxicity studies to determine immediate effects of high doses.
- Chronic toxicity studies to observe long-term effects of small doses.
- Carcinogenicity and mutagenicity tests to check for cancer-causing or DNA-damaging properties.

- Reproductive and developmental toxicity assessments.
- From this data, scientists determine the No-Observed-Adverse-Effect Level (NOAEL) - the highest dose at which no harmful effects are observed.

2. Establishment of ADI (Acceptable Daily Intake)

- Once the NOAEL is determined, a safety factor (usually 100) is applied to account for human variability. This leads to the establishment of the Acceptable Daily Intake (ADI) - the amount of an additive that can be consumed daily over a lifetime without health risk.
- For example, if the NOAEL is 100 mg/kg body weight, the ADI might be set at 1 mg/kg.

3. Regulatory Approval and Oversight

- Only additives approved by national or international food safety authorities (such as FSSAI, USFDA, EFSA, or Codex Alimentarius) are allowed in food. Each additive is evaluated: For its intended use, In specific food categories, Within defined limits
- They are periodically reviewed based on new research. Banned or restricted additives are immediately removed from use if shown to pose a risk.

4. Possible Health Risks

Even though most additives are safe within limits, overuse or prolonged exposure can lead to health problems

- Some synthetic colours and preservatives are linked to hyperactivity in children.
- Long-term use of nitrates and nitrites (used in meats) has been linked to an increased risk of cancer.
- Some individuals may have allergic reactions or intolerances to additives like sulphur dioxide, MSG, or benzoates.

5. Labelling Requirements

To protect consumer health, regulations mandate that all permitted food additives must be clearly listed on food labels, often with their INS or E-number, so that consumers can make informed choices especially important for those with allergies or sensitivities.

6. Monitoring and Surveillance

- Food regulatory agencies monitor additive use through: Random food sampling, Periodic inspections, Market surveillance, Reporting systems for adverse effects
- This ensures that the additives remain within safe limits and are used according to regulations.

4.12 CONCLUSION:

In conclusion, food preservatives and additives play a crucial role in enhancing the shelf life, safety, appearance and flavour of food products. The classification of these substances based on their functions such as antioxidants, antimicrobials, flavour enhancers and colorants help in understanding their specific roles in food processing. Their applications span across a wide variety of food products, ensuring stability, freshness and consumer appeal. The enforcement of permissible limits by regulatory authorities like FSSAI, FDA and Codex Alimentarius ensures these substances are used safely and within health-protective boundaries. Attention to safety aspects is essential, as excessive or improper use can pose health risks. Therefore, it is vital to use only approved preservatives and additives, follow good manufacturing practices and continuously assess their impact on health to maintain food quality and consumer trust.

4.13 SUMMARY:

Food preservatives and additives are classified based on their functions such as antimicrobials, antioxidants, flavour enhancers, colorants and emulsifiers. Their application ensures longer shelf life, improved taste, appearance and texture of food products. Permissible limits, set by food safety authorities like FSSAI and FDA, regulate their safe usage to avoid harmful health effects. The safety aspects focus on using only approved substances, adhering to guidelines and monitoring potential health risks. Overall, responsible use of preservatives and additives is essential for food quality, consumer safety and industry standards.

4.14 TECHNICAL TERMS:

Antimicrobial Preservatives**,** Antioxidants**,** Chelating (Sequestering) Agents**,** Class I & II Preservatives**,** Acceptable Daily Intake (ADI)**,** Good Manufacturing Practice (GMP)

4.15 SELF ASSESSMENT QUESTIONS:

- What are food preservatives and how are they classified?
- Why is it important to regulate the permissible limits of food additives?
- What are the potential health risks of exceeding the acceptable daily intake (ADI) of additives?
- List any three common applications of food preservatives in processed foods.
- What safety measures should be followed while using food preservatives in manufacturing?

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Dr. Santhi Sri, K.V

LESSON-5

METHODS OF FOOD PROCESSING AND PRESERVATION: PROCESSING AND PRESERVATION BY HEAT - PRINCIPLES OF THERMAL PROCESSING

5.0 OBJECTIVES:

After reading this chapter, students will be able to learn about

- Methods of food processing
- Principles of thermal processing

STRUCTURE:

5.1 INTRODUCTION

Food preservation has likely existed for as long as humanity or Homo sapiens. Evidence of turning the excess grape harvest into wine and conserving milk by producing yogurt, cottage cheese, butter, and ghee may be found in historical records going back to 3000 years B.C. The practice of sun-drying fruits, vegetables, meats, and other foods is more ancient than written history and was common even before humans discovered fire. The development of food processing and preservation has been significantly influenced by the Indian subcontinent.

The practice of handling and treating food to avoid food borne illness and to stop or significantly slow down its spoiling while preserving its flavor, texture, and nutritional value is known as food preservation. The collection of procedures and methods used to turn raw materials into food that can be consumed by people or animals is known as food processing. These procedures are used in the food processing sector. Clean, harvested or butchered ingredients are frequently transformed into enticing, marketable food products through food processing.

5.2 METHODS OF FOOD PROCESSING AND PRESERVATION

5.2.1. Heat addition (also known as thermal processing):

Heat treatment helps preserve food by deactivating enzymes and eliminating bacteria that cause spoiling and pose a health risk to the general population. The food can be kept in storage for a long time if it is properly wrapped to avoid recontamination. While the commercial sterilizing process (canning) creates products that are shelf-stable, pasteurization procedures only use mild heat and are intended to provide a temporary extension of shelf life when combined with refrigeration. Foods are made safer and more appetizing by the heat treatment that is accomplished during cooking.

5.2.2. Heat removal (also known as cooling or refrigeration):

Since the majority of biological, biochemical, physiological and microbiological activities change in response to temperature, temperature management (also known as refrigeration) is still the most popular way to preserve food in modern times. Refrigeration simply extends the shelf life temporarily since spoiling activities are not totally stopped. However, with the exception of some enzymatic and chemical changes, freezing stops the majority of these physiological and microbiological processes. Particularly when the product is frozen and kept at temperatures lower than -18^{o}C, the freezing procedure can offer a lengthy shelf life.

5.2.3. Moisture removal (also known as drying or dehydration):

Water, which is present in food as free moisture is necessary for all life-sustaining processes. Food can be made stable by eliminating or lowering its moisture content as this stops or delays the majority of spoiling processes. This idea is applied in processing applications like evaporation, drying and concentration.

5.2.4. Regulating water activity

Food instability is not solely caused by the presence of moisture. It is the moisture that is available for their activities. The amount of moisture that is available is measured by water activity. For the majority of activities, a water activity level of 0.75 is thought to be the minimum. Water becomes unavailable when it is bonded to larger molecules, such as sugars, salts, or others. Concentrates, foods with intermediate moisture content, dried goods, etc., may have these kinds of circumstances.

5.2.5. Preservatives:

Sugar, salt and acid are added to foods each with a specific function in a product. Preservatives have the ability to specifically regulate the actions of enzymes and microbes. Salt and sugar can regulate water activity. Certain acids, like vinegar and acetic acid have antibacterial qualities. These ideas are used in products like jams, jellies, preserves, pickles, bottled drinks etc.

5.2.6. Other methods:

A variety of methods including irradiation, UV light exposure, high-intensity pulsed light, pulsed electric field, high pressure and others have been employed to extend the shelf life of goods and control their rate of spoiling. Additionally, food processing has secondary goals. These include preparing food ingredients through isolation or synthesis, producing non conventional foods, facilitating marketing, offering end use convenience and diversifying products to offer diversity, flavor and nutrition.

5.4 PRINCIPLES OF THERMAL PRESERVATION

Preservation of fruit and vegetables by the application of heat is one of the most important methods of food preservation. This is because it not only imparts desirable effects to the eating quality of the food but also exerts a preserving effect by the destruction of microorganisms, enzymes, insects, and parasites. This method also significantly influences the technology of handling, packaging, and processing.

Other advantages of heat processing include the destruction of anti-nutritional factors (e.g., the trypsin inhibitor in some legumes) an improvement in the availability of some nutrients (e.g., improved digestibility of proteins, gelatinization of starches, and the release of bound niacin) the production of shelf-stable foods that do not require refrigeration and above all it offers a relatively simple control of processing conditions.

The disadvantages of heat processing include alteration or destruction of sensory quality of foods like flavor, colour, taste and texture. As a result the heat processed foods are perceived to have different quality as compared to the fresh produce.

Preservation by heat (thermal processing and canning) thus involves heating of foods in hermetically sealed containers. Most of the raw material used for canning is usually contaminated with different species and strains of bacteria, molds and yeast undergoing different stages of growth. Amongst these, bacterial spores are more difficult to inactivate. Thus, the criteria for heat processing chosen to inactivate the spores are also presumed to be capable of inactivating all the other forms of microorganisms.

Unlike fruits, most vegetables being low or non-acidic require a severe heat treatment to kill most of the bacteria. It is therefore necessary to work out the proper time and temperature relationship for each category of food.

Heat transfer is an operation that occurs repeatedly in the food industry. Whether it is cooking, baking, drying, sterilizing or freezing, heat transfer is part of the processing of almost every food. Heat transfer is a dynamic process in which heat is transferred spontaneously from one body to another body (cooler). The rate of heat transfer depends upon the differences in temperature between the bodies.

The greater the difference in temperature, the greater will be the rate of heat transfer. An increase in the temperature difference increases the driving force and therefore, increases the rate of heat transfer. These factors are connected by the general equations:

Rate of heat transfer = driving force/ resistance.

Rate of heat transfer = temperature difference/heat flow resistance of medium

During processing, temperatures may change and therefore, the rate of heat transfer will change. This is called unsteady state heat transfer (heating and cooling of cans in a retort to sterilize the contents), in contrast to steady state heat transfer when the temperatures do not change. Unsteady state heat transfer is more complex since an additional variable time enters into the rate equations.

Mode of Heat transfer: Most of the unit operations in food processing involve the transfer of heat into or out of the food. There are three modes of heat transfer:

i) Conduction: It is the movement of heat by direct transfer of molecular energy within solids. In conduction, the molecular energy is directly exchanged from the hotter to the cooler regions. An example of conduction is the heat transfer through the solid walls of a refrigerated store. Heat transfers from one particle to another by contact and the food particles in it cannot move.

ii) Convection: It is the transfer of heat by the movement of groups of molecules in a fluid. The groups of molecules may be moved by either density changes (as in heated air) or by forced motion of the fluid (or agitation as in stirred liquids). An example of convection heating is cooking in a jacketed pan, density changes cause heat transfer by natural convection whereas with a stirrer, the convection is forced.

iii) Radiation: The energy transfer through a medium which itself is not heated is called radiation. The transfer of heat energy by electromagnetic waves, which transfer heat from one body to another, in the same way as electro-magnetic light waves transfer light energy. An example of radiant heat transfer is when food stuff is passed below a bank of electric resistance heaters that are red-hot.

In general, heat is transferred in solids by conduction, in fluids by conduction and convection. Heat transfer by radiation occurs through open space, can often be neglected and is most significant when temperature differences are substantial. In the majority of applications, all the three types of heat-transfers occur simultaneously but one type may be more important than others in particular applications. For example, in canning of fruits and vegetables both conduction and convection takes place.

Mechanism of Heat Transfer

i) Steady-state heat transfer: Steady state heat transfer takes place when there is a constant temperature difference between two materials.

ii) Unsteady state heat transfer: It is the mechanism when the temperature of the food and/or heating or cooling medium are constantly changing. It is commonly used in the majority of foods.

5.5 PROCESSING AND PRESERVATION BY HEAT

Thermal processing refers to the regulated application of heat to raise or lower, depending on the situation, the rates of reactions in food, which may be chemical, enzymatic, microbiological, or other types.

i) Effect of thermal processing on microbiological activity

The main goals of thermal procedures are to establish conditions that restrict the growth of harmful and spoilage microorganisms and to eradicate or reduce the quantity of germs of public health concern to an acceptable level (commercial sterility). Sterilization procedures are designed to create shelf-stable items with a long storage life, whereas pasteurization treatments depend on keeping processed foods in a refrigerator for a predetermined maximum amount of time. From a public health perspective, the primary requirement for sterilizing low-acid foods (pH>4.5) is the destruction of C. botulinum, while other spoilage-type microbes are used for acidic foods.

ii) Effect of thermal processing on enzyme activity

Even when stored in a refrigerator, a number of enzymes (lipoxygenase, pectinesterase, and peroxidase) can alter food quality unfavorably if they are not inactivated. The inactivation of heat-resistant enzymes (pectinesterase, phosphatase, and peroxidase) is frequently utilized as a foundation for the thermal processing of acid foods and the pasteurization of dairy products. Because of their poorer heat resistance compared to other indicator microorganisms or the way the processes are designed to employ them as indicators, the majority of enzymes are inactivated in typical thermal processes. When compared to microorganisms, some of these oxidative enzymes have been shown to have extremely low temperature sensitivity.

iii) Effect of thermal processing on food quality

The use of food processing methods that increase the shelf life of perishable foods also reduces the availability of certain vital nutrients. In recent years, the food sector has faced significant challenges in maximizing nutrition retention during thermal processing. From the perspective of food processing, the main issue is the unavoidable loss of nutritious components that are heat-labile and partially destroyed by heat. The type of heat process (sterilization, pasteurization, or blanching) determines how much of these losses occur.

Using the right time, temperature, and processing conditions, along with the right environmental factors (pH, concentration, etc.) for the particular food product and its target essential nutrient, is the main focus of food processing operations in order to minimize these unavoidable losses.

Thermal Processing

i) Blanching

Perhaps the least intense of the aforementioned procedures is blanching; yet, leaching or other factors might cause nutritional loss during this process. The two most popular blanching methods are steam and hot water blanching. These traditional methods are straightforward and low-cost, but they also use a lot of energy, produce a lot of effluent, and cause significant leaching of soluble components (which happens during both heating and cooling).

Leaching losses and effluent volume can both be considerably decreased using steam blanching. It has been demonstrated that the individual quick blanching (IQB) method, which is based on a two-stage heat-hold approach, greatly enhances nutrient retention. In the second step, the veggies are kept in a deep bed long enough to cause the enzymes to become inactive after being cooked in single layers to a temperature high enough to do so.

Blanching can result in a loss of up to 40% for minerals and vitamins (particularly vitamin C and thiamin), 35% for sugars, and 20% for proteins and amino acids, depending on the process, commodity, and nutrients involved. The thermal degradation of blue/green chlorophyll pigments to yellow/green pheophytins during blanching might cause some unwanted color changes.

Both pH and the presence of metal ions can affect chlorophylls. Chelating compounds and an alkaline pH promote improved green color retention. Low-temperature blanching has been demonstrated to enhance the texture of certain items (carrots, beans, potatoes, tomatoes, and cauliflower) by activating the pectin methyl esterase enzyme, whereas texture deterioration is a feature of other heat treatments.

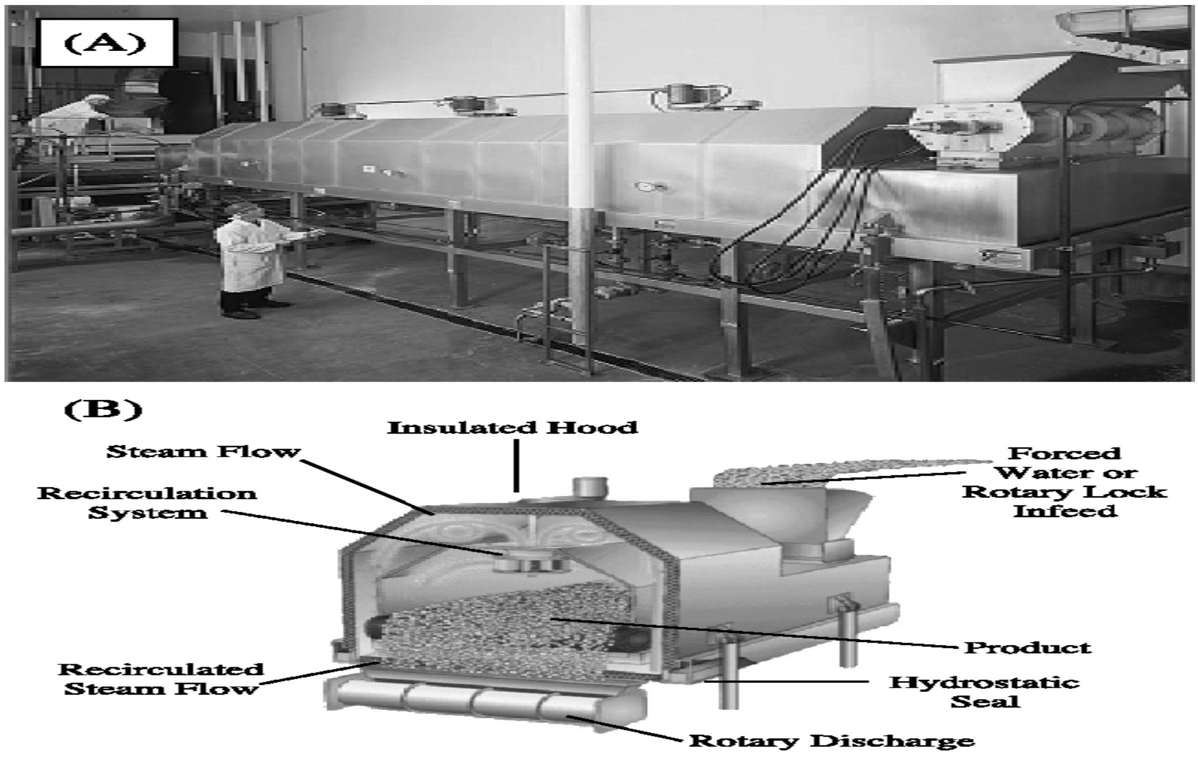

Fig. 5.1: Turbo-Flow forced convection steam blancher (A); (B) schematic representation of the transversal section (Courtesy of Key Technology, Inc.)

ii) Pasteurization

While less extreme than sterilization, pasteurization is a heat treatment that is used on food to inactivate specific disease-causing organisms that are important in a given food. Most viable vegetative forms of microorganisms are rendered inactive by pasteurization, although heat-resistant spores remain unaffected. Pasteurization was initially developed to render bovine TB in milk inactive. Ratios of about 1015:1 decrease the number of living things. Pasteurization may be taken into consideration in connection to dietary enzymes that can be rendered inactive by heat, in addition to its use to render bacteria inactive. Pasteurization follows the same broad relationships that were covered under sterilization.

It is necessary to use a temperature and time combination that is adequate to deactivate the specific bacterial or enzyme species in question. Thankfully, the majority of harmful organisms that might spread from food to the consumer are not highly heat-resistant. Pasteurization of liquid milk is the most widely used. Due to the modest heat treatment used during the pasteurization process, we now know that the majority of foods' nutritional and sensory qualities are only marginally impacted. However, the product quality keeps changing (deteriorating) while being stored because it is merely a short-term solution to extend the shelf life.

Fig. 5.2: Automatic milk pasteurization unit (FH Scandinox & co)

The storage environment and post-pasteurization packaging conditions affect the shelf life. This has drawn a lot of attention to milk, the most significant nonacid liquid food. Since fat-soluble vitamins A, D, E, and K are not very sensitive to heat, pasteurizing milk usually does not result in any loss of these vitamins. Less than 10% of thiamin, vitamin B6, vitamin B12, and folic acid are lost as a result of pasteurization. Up to 25% of vitamin C can be lost. Pasteurization does not significantly alter the color of milk.

The primary cause of the color variations between raw and pasteurized milks is homogenization. When pasteurization is done with a modest heat treatment, some volatile fragrance components are lost. The presence of oxygen and the activity of the enzyme polyphenoloxidase are the primary causes of color changes in fruits and vegetables. To reduce fruit and vegetable color deterioration, deaeration before pasteurization eliminates oxygen, and heat treatment inactivates the enzyme.

iii) Sterilization

In comparison to the heat treatment typically used to achieve commercial sterility, sterilization procedures are more stringent. It goes without saying that these items will lose some of their nutrients. Vitamins A, B1, B6, B12, C, D, E, folic acid, inositol, and pantothenic acid, as well as amino acids like lysine and threonine, are more susceptible to being destroyed by heat.

Fig 5.3: Food Sterilizer

The impact of the process is difficult to measure because there are many (infinite) time-temperature combinations that can be used to achieve thermal sterilization. The pH of the food (low-acid foods need more intense heat treatment to destroy C. botulinum); the food's composition (high sucrose, protein, and fats make microorganisms more heat resistant); the food's heating behavior (conduction, convection); the type, size, and shape of the container; and the type and method of application of the heating medium all influence how severe the heat treatment is. Processing agitation provides extra variables to improve the process. Certain bacterial species have been chosen as indicator organisms as a result of research on the microorganisms found in food. Of the bacteria that are likely to cause problems in foods, these are the hardest to eradicate in their spore forms.

Thermal Death Time

Heat has been shown to kill microorganisms, including C. botulinum, at varying rates depending on the temperature; spores are killed more quickly at higher temperatures. Some spores appear to be more heat resistant than others, and the spores are killed at varying times at any given temperature. Experimental research has shown that the number of surviving spores asymptotically falls to zero when plotted against the time of keeping at any selected temperature.

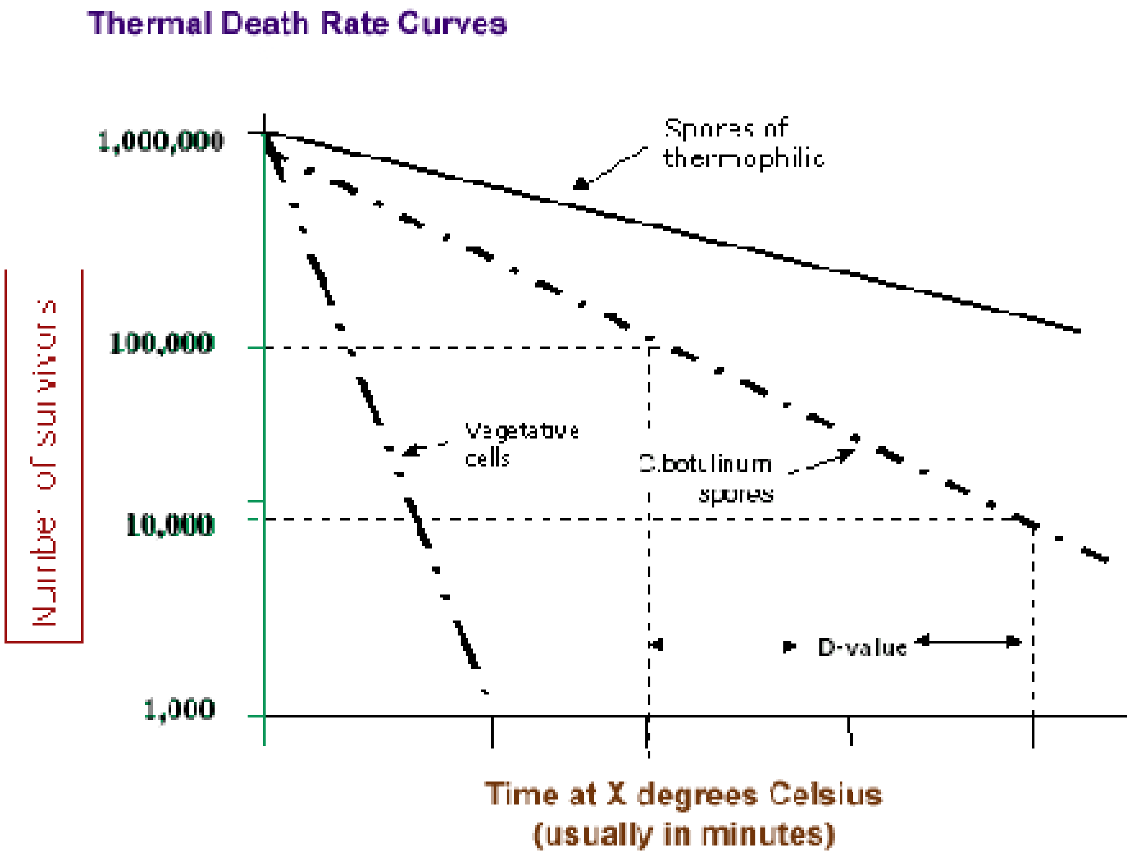

Fig 5.4: Thermal Death Rate curves

In circumstances that are somewhat comparable to those of M. tuberculosis, the milk enzyme phosphatase is eliminated. Its presence is interpreted as evidence that heat treatment is inadequate because chemical assays for the enzyme are simple. In this case, the product's suitability for human consumption or storage is unaffected by the presence or lack of phosphatase. Pasteurization and sterilization are two examples of how heat transfer is used as a unit operation in food processing. Once the required temperatures and durations have been determined, the equipment for heat transfer is designed using the equations developed for heat transfer operations.

5.5 SUMMARY:

Food preservatives maintain and guarantee safe and nutritious food for long-term use. Examples of preserved foods are products packaged in the refrigerator, canned, and dried. There are five benefits that can be gained from food preservation. With preservation, the shelf life of the food can be extended. By adding additives, industries can expand the supply chain worldwide. The process of preservation saves time and energy because the preserved food has been partially processed. To have a better food safety management system to protect food production, industries can also consider implementing a food safety management system (FSMS) or hazard analysis critical control point (HACCP) along with preservation techniques.

5.6 TECHNICAL TERMS:

HACCP, FSMS, Hazards, Blanching, Thermal Death Time

5.7 SELF-ASSESSMENT QUESTIONS:

1) What is HACCP?
2) Write about methods of preservation of foods.

5.8 SUGGESTED READINGS:

1) Preservation of Fruits and Vegetables by Girdhari Lal and Siddappa G.S.
2) Food Processing Technology: Principles & Practice, 2nd Edition by P.J. Fellows

Dr. B. Babitha

LESSON-6

BLANCHING, PASTEURIZATION, UHT PROCESSING, THERMAL STERILIZATION, CANNING, EXTRUSION

6.0 OBJECTIVES:

After reading this chapter, students will be able to learn about

- Methods of food processing like blanching, pasteurization, UHT processing, thermal sterilization, canning, and extrusion.

STRUCTURE:

6.1 INTRODUCTION

In food processing, heat treatment is still one of the most crucial techniques; because it not only improves the quality of food, but it also preserves food by destroying enzymes, microorganisms, insects and parasites.

Conversely, heat can damage the flavor, color, taste, and texture compounds, making food appear lower quality. This drawback is overcome by using higher temperatures and shorter heat-processing times, a method that capitalizes on the varying D-values of desirable components versus microbes and enzymes. This High-Temperature Short-Time (HTST) processing is engineered to maintain the food's sensory qualities and nutritional value while still achieving the required level of microbial and enzyme inactivation that longer, lower-temperature methods provide.

6.2 BLANCHING

Blanching primarily serves to inactivate enzymes in vegetables and some fruits before further handling. Consequently, it is intended as a pretreatment step, usually occurring between raw material preparation and subsequent processing, not as the sole method of preservation.

For canning, particularly of large cans, foods must be blanched beforehand because the extended time required reaching sterilization temperatures can allow enzyme activity to begin. In fact, under blanching is a significant risk: the heat may be just enough to disrupt tissues and combine enzymes with their substrates, but not enough to inactivate the enzymes, thereby accelerating the damage more than if the food had not been blanched at all.

Furthermore, only some enzymes may be eliminated, which speeds up deterioration and increases the activity of other enzymes. The D and z values of enzymes indicate their heat resistance. Enzymes such as lipoxygenase, polyphenoloxidase, polygalacturonase and chlorophyllase degrade the nutritional value and eating appeal of fruits and vegetables. Catalase and peroxidase are two heat resistant enzymes that are present in the majority of vegetables. They serve as marker enzymes to assess the effectiveness of blanching even though they do not degrade after storage.

Since peroxidase is more heat resistant than the other enzyme, its disappearance would suggest that other, less heat-resistant enzymes have also been killed. The temperature of the heating medium, the convective heat transfer coefficient, the size and shape of the food pieces, and the foods thermal conductivity may all be summed up as the variables that affect the rate of heating at the products center.

Steam Blanchers

When water sprays are used at the inlet and outlet to condense escaping steam, the energy consumption efficiency is 19%. To cut down on steam losses and boost energy efficiency to 27%, food can also enter and exit the blancher using rotary valves or hydrostatic seals. Alternatively, steam can be recycled by going through Venturi valves. When hydrostatic and venturi devices are used together, energy efficiency is increased by 31%. Conventional steam blanching frequently results in uneven heating across the food's several layers. Food gets overheated at the borders and loses texture and other sensory qualities as a result of the time-temperature combination needed to guarantee enzyme inactivation at the center of the bed.

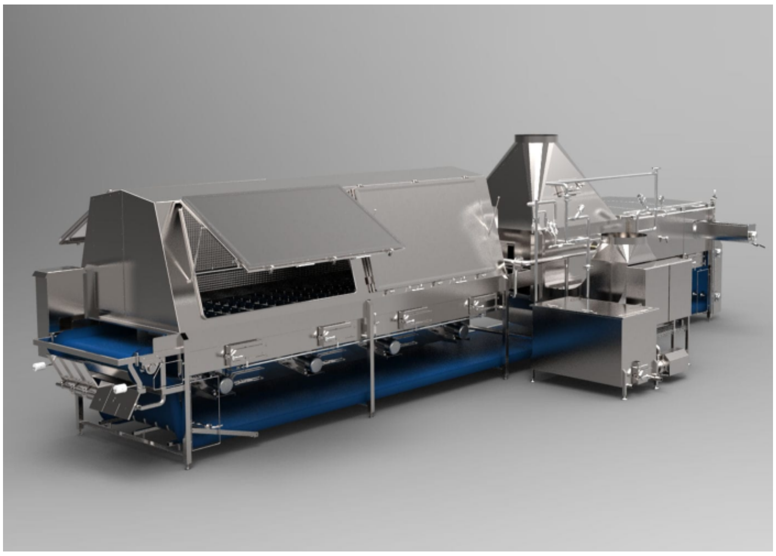

Fig. 6.1: Industrial Steam Blancher

Individual Quick Blanching

Individual quick blanching (IQB), a two-stage blanching method was created to address this issue. The first step involves heating the food in a single layer to a temperature high enough to render enzymes inactive. The second step known as "adiabatic holding," involves keeping a deep bed of food for long enough for the temperature in the middle of each piece to rise to the level required for enzyme inactivation. The efficiency of energy usage is improved to 86-91% when the heating time is shortened (for instance, 25 seconds for heating and 50 seconds for holding 1 cm chopped carrot as opposed to 3 minutes for traditional blanching).

When small particulate foods (such peas or sliced or diced carrots) are blanched, the mass of product blanched per kilogram of steam rises from 0.5 kg per kilogram of steam in traditional steam blanchers to 6-7 kg per kilogram of steam. During a brief first drying process known as "pre-conditioning," the food is exposed to warm air (65ºC) to minimize nutrient losses during steam blanching. During IQB, the surfaces collect condensing steam after the surface moisture evaporates. Only 5% of the weight loss observed with traditional steam blanching is lost.

Hot-Water Blanchers

Blanchers come in a variety of configurations, all of which hold food in hot water between 70 and 100 degrees Celsius for a predetermined amount of time before removing it to a dewatering and cooling section. Food passes through a gently spinning cylindrical mesh drum that is partially immersed in hot water in the commonly used reel blancher. Internal flights carry the food through the drum. The length and rotational speed regulate the heating duration. A continuous, insulated metal pipe with feed and discharge ports makes up a pipe blancher. Food is metered in and hot water is recirculated through the pipe. The length of the pipe and the water's velocity affect how long food stays in the blancher.

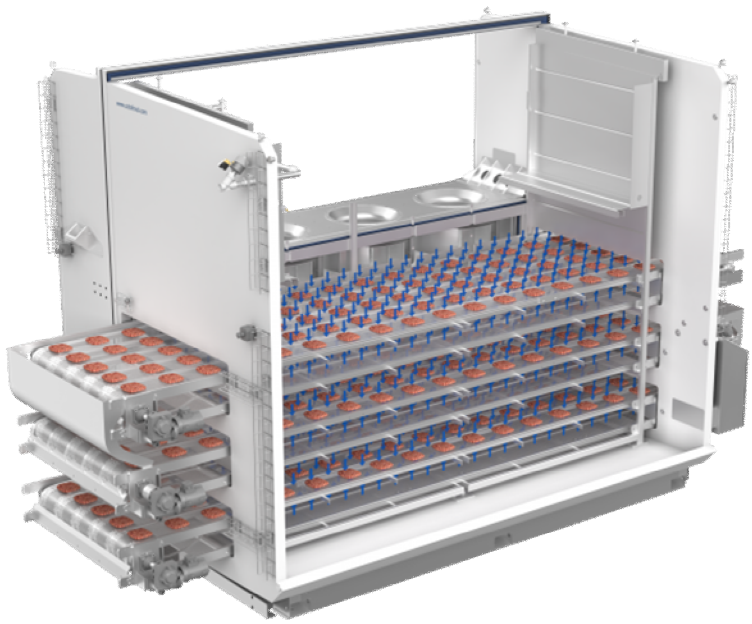

Fig. 6.2: Individual Quick blanchers

The same heat exchanger is used in both systems to heat the pre-heat water and chill the cooling water at the same time. It recovers up to 70% of the heat. The food is first blanched using a recirculated water-steam mixture, and then it is finally cooled using cold air. Water usage is kept to about 1m3 per 10t of product, and wastewater output is minimal. In contrast to 0.25-0.5 kg per kilogram in traditional hot-water blanchers, 16.7-20 kg of goods are blanched for every kilogram of steam. An alternate design used for blanching peas, spinach, lima beans and broccoli.

6.3 PASTEURIZATION

Food is cooked to less than 100°C during the relatively gentle heat treatment known as pasteurization. It is used to prolong the shelf life of goods for many days and reduce potential health risks from pathogenic microorganisms in low acid meals (pH 4.5, such as milk). By eliminating rotting microorganisms (like molds or yeasts) and/or inactivating enzymes, it prolongs the shelf life of acidic goods (like bottled fruit) by several months. The nutritious value or sensory qualities of both kinds of food are hardly altered.

Canning is related to processing foods that have a naturally low pH (like fruit pieces) or those have the pH purposefully lowered (like pickles). The modest heat treatment used is commonly referred to as pasteurization. This chapter describes the use of heat exchangers to pasteurize liquid meals that are either unpackaged or packaged in containers.

For instance, the holder procedure, a lower-temperature, longer-time method of processing milk that runs at 63ºC for 30 minutes, results in somewhat more vitamin loss and more flavor alterations than HTST processing, which runs at 71.8ºC for 15 seconds. It is also less commonly utilized. Higher-heat shorter-time processing, sometimes known as “flash pasteurization,” involves higher temperatures and shorter processing times (for instance, 88ºC for 1s, 94ºC for 0.1s, or 100ºC for 0.01s for milk). Raw milk naturally contains an enzyme called alkaline phosphatase, which has a D value comparable to that of heat-resistant bacteria.

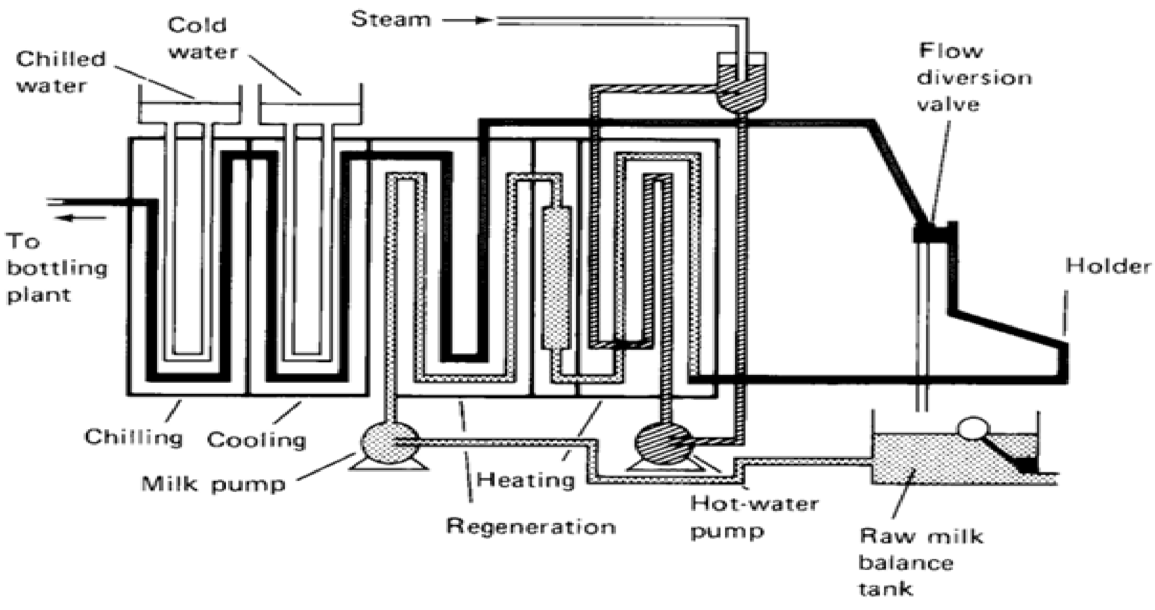

Fig. 6.3: Mechanism of Pasteurization through plate Heat Exchangers

6.4 UHT PROCESSING

Sterilization of the product prior to filling it into pre-sterilized containers in a sterile atmosphere allows for higher processing temperatures for shorter processing times. This serves as the foundation for aseptic processing, another name for UHT processing. Milk, fruit juices and concentrates, cream, yoghurt, wine, salad dressing, eggs, and ice cream mix are just a few of the liquid items that it is used to sterilize. Foods with tiny, distinct particles, such as cottage cheese, baby food, tomato products, fruit and vegetables, soups, and rice desserts, can also be processed with it. Larger-particulate food processing methods have been developed, and ohmic heating has been successfully applied to UHT processing in more recent times.

The superior quality of UHT foods makes them competitive with frozen and chilled goods. UHT also has the significant benefit of having a minimum six-month shelf life without refrigeration. While the sterilization time remains the same with aseptic processing, the processing time increases to 218 minutes when the can size is increased to A10. This enables the utilization of extremely large containers, such as 1 tonne aseptic bags of liquid egg or tomato puree, which are utilized as ingredients in other production processes. The cost and complexity of the plant, which result from the need to sterilize packaging materials, related pipework and tanks, the upkeep of sterile air and surfaces in filling machines and the increased skill levels needed by operators and maintenance personnel are the primary drawbacks of UHT processing.

In a continuous heat exchanger, food is heated in comparatively thin layers while the sterilization temperature and holding time are carefully regulated. To make sure that microbial spores cannot survive the process, it is crucial to determine how long it takes for any particle to pass through the holding section and how quickly heat moves from the liquid to the particle's center. A common calculation is to double the holding tube's length by the average liquid flow rate. Because the variety of residence durations is less, it is also crucial to achieve turbulent flow, if at all possible.

If deaeration is also necessary, the sterile product is chilled in a vacuum chamber or in a second heat exchanger. Laminated cartons are frequently utilized since containers do not have to endure sterilization conditions. In terms of pack cost as well as transportation and storage expenses, they are far more cost-effective than cans and bottles. Hydrogen peroxide is used to pre-sterilize cartons, while filtered air and UV light are used to keep filling machinery contained and sterile.

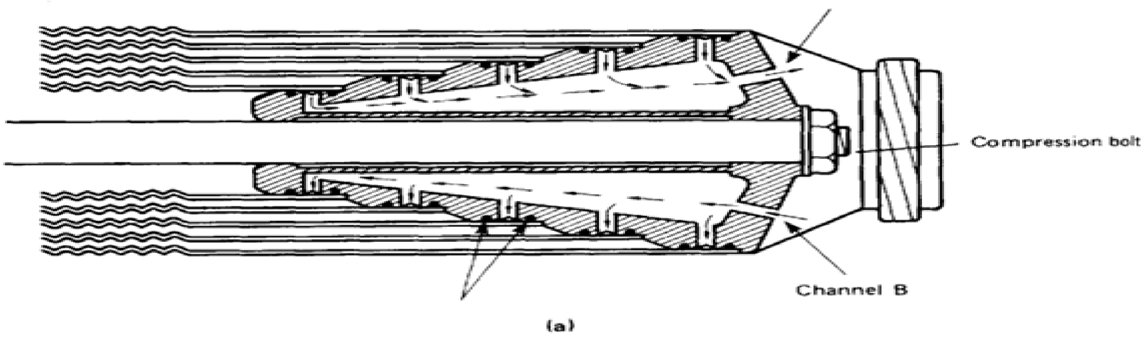

Fig. 6.4: Concentric Tube heat Exchanger with channels

6.5 THERMAL STERILIZATION

The process of heating food to a high enough temperature and for a long enough period of time to eliminate microbial and enzyme activity is known as heat sterilization. Because of this, sterile meals can be stored for more than six months at room temperature. Foods' nutritional value and sensory appeal may be significantly altered by the intense heat treatment used in the outdated in-container sterilization (canning) procedure.

In Container Sterilization

The heat resistance of any microorganisms or enzymes that may be present in the food, the heating conditions, the food's pH, the size of the container, and the physical condition of the food all affect how long it takes to sterilize a food. Both the rate of heat penetration into the food and the heat resistance of microorganisms, especially heat resistant spores or likely-to-be-present enzymes, must be known in order to calculate the processing time for a particular item.

Retorting

The capacity of the container to fully isolate the food from the surroundings affects how long sterile foods last on the shelf. There are four main categories of heat-sterilizing containers: 1. Cans made of metal 2. Glass bottles or jars 3. Pliable pouches 4. Stiff trays. The technique known as "exhausting" must be used to remove air from filled containers before they are processed. This lessens the strain on the container by preventing the air from expanding with the heat. In certain foods, the elimination of oxygen also stops oxidative alterations and interior deterioration. When the air is replaced with steam, a partial vacuum is created in the head space as it cools.

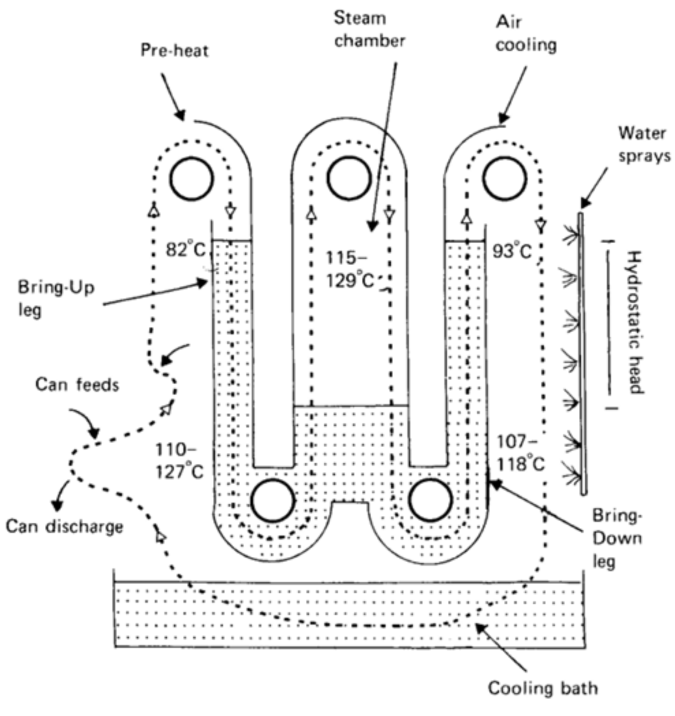

Fig. 6.5: Continuous Hydrostatic Sterilizer

6.6 CANNING

The process of canning entails heating food items in hermetically sealed containers for a predetermined amount of time at a predetermined temperature in order to eradicate bacteria and microbial pathogens that pose a risk to public health, as well as enzymes that cause food to decay while being stored.

Can Manufacturing:

For both domestic and international trade, fruits and vegetables are mostly canned in metal cans. Open top sanitary (OTS) cans are made from tin plates, which are incredibly thin steel sheets that have been lightly coated on both sides with tin (0.00025 cm thick). Tin cans are chopped into the proper sizes using trimming and slitting equipment. The parts give blanks for the bodies. To make hooks, the flat can body is sliced, notched, and then passed through an edging machine. The can body is then twisted into a cylindrical shape and a side seam is welded. These activities are carried out in the can manufacturing factory.

Procedures for canning fruits and vegetables

1) **Fruit and Vegetable Preparation:** Food products are prepared for canning by washing, sorting, grading, peeling, halving, blanching and other processes.

2) **Selection and Receipt of Raw Materials:** Fruits for canning should be firm but ripe, uniformly mature, and free of defects, insect damage, and deformities. Harvesting at the right maturity is therefore a crucial step in choosing the raw materials for canning. The majority of fruits are picked when they are softly ripe. On the other hand, mature bananas, apples, pears, and peaches are the best for canning. While underripe or immature fruit typically shrivels or toughens when canned, overripe fruit produces a lower-quality result. With the exception of peas, beans, and the like, vegetables are collected when they are old enough to tolerate cooking during sterilization.

3) **Washing:** To get rid of dust, grime and surface microflora that stick fruits and vegetables are often rinsed with water. Since they are lye peeled fruits like apricots and peaches do not need to be cleaned before being peeled. However, washing after peeling should be avoided as it eliminates vitamins and minerals. There are various ways to wash such as soaking or stirring in water using hot or cold water sprays etc. In mechanical washers, the product is agitated or tumbled on rotating screens or moving belts while submerged in water or exposed to water sprays.

4) **Sorting and Grading:** This process guarantees that subpar or damaged goods are eliminated. In addition to skilled workers who identify subpar produce unfit for canning an inspection belt can be employed for sorting. Sorting can be done with automatic color sorters to save labor costs. Following initial sorting, the fruits and vegetables are evaluated to achieve consistent quality in terms of size, color etc. The two methods of grading are manual and machine-assisted. The fruit and vegetables are run through screens with varying-diameter holes for mechanical grading.

   There are several kinds of mechanical graders such as rope or cable graders, screen graders and roller graders. The most widely used screen graders have copper vibrating screens with circular apertures. Typically, a set of six screens is offered to accommodate varying screen sizes. Berries and soft fruits are typically assessed by hand. While peaches, apricots, pears, mangoes and other fruits are assessed after being cut into halves or slices for canning. Plums, cherries and olives are graded whole. Cap size is used to grade white button mushrooms. Only light, healthy buttons with a compact head and a cap diameter of up to 2.5 cm are rated as A grade, buttons with a cap diameter larger than 2.5 cm are rated as B grade.

The main unit activities for getting fruit and vegetables ready for canning are peeling, coring and pitting. Peeling and coring techniques are chosen based on the commodity type such as using a

- knife or hand,
- machine
- applying heat treatment
- Lye solution.

Fruits such as apples, peaches, apricots, and others have their cores and pits removed either manually or by a machine called a de-corer.

a) **Manual peeling:** Using peeling knives, a lot of fruits and vegetables are manually peeled and sliced. When dealing with odd fruit forms, a peeling knife with a curved blade and a specific guard to control the depth of peeling can be utilized for consistent peeling.

b) **Mechanical peeling:** Pears, apples, carrots, turnips, potatoes, and other vegetables can be peeled using mechanical peeling, coring, and cubing equipment. In a similar manner, cherries and peaches are peeled using automatic peelers.

c) **Mechanical knife peeling:** Fruits like apples and pears are peeled using mechanical knife peelers. In a mechanical knife peeler, the skin is removed by pressing either stationary blades against the rotating food's surface or revolving blades against the stationary food.

d) **Abrasive peeling:** This method is used to peel carrots, potatoes, ginger and other vegetables. The food item is either put into a revolving bowl lined with carborundum crystal, which serves as an abrasive surface or fed onto the carborundum rollers. The skin is removed from the foods surface by the rotating abrasive surface using a constant supply of water.

e) **Flame peeling:** Brinda, garlic and onions are all subjected to flame peeling. The peeler is made out of a conveyor belt that rotates and moves food through a furnace that is heated to above 1000 degrees Celsius. The onions charred skin is carefully removed after the outer layer and root hairs are burned off.

f) **Peeling by heat or hot water:** This technique involves scalding peaches and potatoes in boiling water or steam to soften and loosen the skin which is then manually removed. Apples and tomatoes can also be peeled using infrared heat peeling.

g) **Flash steam peeling:** This method involves feeding the fruit and vegetables into a pressure vessel that rotates slowly (4-6 rpm). Then, depending on the type of fruit, high pressure steam (1500 kPa) is added to the revolving vessel, exposing all food surfaces to the steam for a predetermined amount of time. The foods surface flashes off when the pressure is abruptly removed because of the steam that has collected beneath the epidermis. The majority of the peeled material is released using steam, and any remaining skin traces are eliminated with subsequent water sprays.

h) **Lye peeling:** To peel, a boiling aqueous solution of either potassium hydroxide (1-2%) or caustic soda (Sodium hydroxide) is employed together with a large amount of water and a heat source. Peaches, nectarines, apricots, sweet orange segments, carrots and sweet potatoes are among the fruits and vegetables that are peeled by dipping them in boiling caustic soda (1-2%) for one to two minutes depending on the fruit or vegetable nature, temperature and maturity. This is followed by dipping in cold water. By gently rubbing the fruit by hand the hot lye separates the skin from the flesh underneath.

5. **Cutting, halving, and slicing:** The fruits are either manually or mechanically cut in half or cored once they have been peeled. To prevent enzymatic browning, peeled fruit should always be kept submerged in either vinegar or water with a 1-2 percent salt solution. Before canning, fruits like tomatoes, pears, peaches, and apricots are peeled. On the other hand, canned fruits retain more nutrients than peeled fruits.

6. **Blanching:** Blanching is the process of briefly treating fruit and vegetables with hot water or steam, then immediately cooling them down before canning. Blanching a primary goal is as follows: To render enzymes inactive prior to processing, the product should be preheated and cleaned to reduce the microbiological load. Softening the fruit tissue makes tight packing easier and encourages the release of the raw fruits intracellular gases, which is necessary to prevent the container from becoming overly compressed. Furthermore, this initial softening facilitates better heat transfer during heat processing, minimizes internal can corrosion and guarantees the successful development of a vacuum in the can.

7. **Filling cans:** To get rid of any adherent dust or foreign objects, tin cans are cleaned in hot water or a steam jet. Before being used the cans are either sanitized by passing through a steam sterilizing tunnel or dipped in a hot water tank. Typically, ordinary cans are used; however lacquered cans are used for colored foods like strawberries, black grapes, plums etc. In accordance with the stated drain weight, the fruits and vegetables, whether in slices, halves, or whole are put into the cans.

8. **Syruping or Brining:** Hot sugar syrup (35–55%) for fruits and hot brine (2–10%) for vegetables are put into the cans. During processing, the goal of syruping or brining is to facilitate the transfer of heat within the food components. Additionally, it fills in the gaps between the fruit or vegetables in the can and enhances the flavor of the canned food. Either manually or automatically, the syrup or brine is added to the can between 79 and 820 degrees Celsius, leaving 0.32-0.47 centimeters of head space. A

horizontal pipe with a row of tiny holes is used in automatic machinery to draw the prepared syrup or brine into the cans.

9. **Exhausting:** This unit procedure involves removing almost all of the air from the can's contents prior to sealing. To prevent microbiological spoiling, an anaerobic atmosphere is created in the container by draining and creating a vacuum. Eliminating air from the contents also lessens the possibility of tin plate corrosion, pin holing and can contents discoloration. Vitamin C is better retained when you are exhausted. Overfilling or underfilling the can is prevented by the expansion and shriveling of the contents during heating (Strawberries shrivel when heated in sugar syrup, yet corn and peas expand when boiled in brine).

   a) **Heat/thermal exhausting:** Cans use heat exhausting. The lidded, loosely sealed or clenched can is either passed through a covered steam box on a moving belt or through a tank of hot water that is between 82 and 87 °C. The cans are positioned in the water exhaust box so that the water level is between 1.3 and 2.5 cm below the tops of the cans. Depending on the type of product the tiresome time can range from five to twenty-five minutes. The temperature at the can's center should be around 79°C after exhaustion. The air within the can is replaced by steam during exhausting, and the can is sealed while still hot.

   b) **Steam flow or steam-vacuum closing:** This method involves injecting high steam pressure into the can headspace right before closing (at 100°C for 5–8 minutes). As a result, steam rapidly replaces all of the air inside the can, condensing to create a vacuum after seaming. When combined with hot fill, steam vacuum closure ensures a very high vacuum within the can.

   c) **High-speed mechanical vacuum sealing:** In this method, cans containing the product and any syrup or brine are run through a clincher, which clinches the cans (first operation roll seam) but does not create an airtight seal. A brief vacuum is applied to the cans to eliminate the free headspace air, but not all of the dissolved gases in the product. Nevertheless, some syrup might be pulled in with the dissolved air during this process.

10. **Seaming/closing:** A double seamer is used to close the cans as soon as they are empty. The process of double seaming involves two steps. In the initial action, the lid-in-position can is held and rotated between two rollers to insert the lid onto the can body hook. Clinching is the term for this process, in which a roller softly slides the lid into the body hook. The second operation roller is then used to press the seam, creating the proper countersink by causing the body hook and cover hook to overlap appropriately.).

11. **Coding/Embossing:** Once the can is closed, its lid must be coded in order to be recognized. Information about the product, such as the lot number, date of packing, product placed in the can, and name of the canning unit, is provided by the code. The can's second lid, or end cover, is coded right before it is sealed.

12. **Heat processing:** To sterilize the contents, the cans are promptly moved to the heating retorts after being sealed. To remove any chance of microbial spoiling, heat processing involves heating cans to a specific temperature and time. Avoid overcooking since it degrades the product flavor, texture, and appearance. Since acid slows the growth of bacteria and their spores, most fruits and acid vegetables can be treated satisfactorily in boiling water (100°C). On the other hand, non-acidic vegetables aside from tomatoes and rhubarb are processed under pressure at higher temperatures of roughly 115-121 degrees Celsius.

6.7 EXTRUSION

A number of unit processes, such as mixing, cooking, kneading, shearing, shaping, and forming, are combined in the process of extrusion. Extruders are categorized based on how they are constructed (single- or twin-screw extruders) and how they operate (cold extruders or extruder-cookers). All varieties work on the same principles: food is conveyed down the extruder barrel after raw ingredients are delivered into it via the screw or screws. Smaller flights further down the barrel limit the capacity and make it harder for the food to travel. It consequently becomes compressed and fills the barrel and the gaps between the screw flights. The screw kneads the material into a semi-solid, plasticized mass as it travels farther down the barrel.

Extrusion cooking, also referred to as hot extrusion, is the process of heating food above 100ºC. In this case, the temperature rises quickly due to frictional heat and any further heating that is applied. After that, the food is moved to the area of the barrel with the tiniest flights, where shearing and pressure are further intensified. Lastly, it is pushed through one or more narrow apertures (dies) at the barrel's discharge end. The food expands to its final shape as it comes out of the die under pressure, and it cools quickly as the moisture is released as steam. It is possible to make a wide range of shapes, such as doughnuts, tubes, strips, squirls, shells, spheres, and rods. Typical items include a large range of expandable, low-density snack foods.

Pasta and meat items can be mixed and shaped using cold extrusion, which keeps the food's temperature at room temperature. Fish pastes, liquorice, surimi, and pet meals are among the products made using low pressure extrusion at temperatures lower than 100ºC. Extrusion cooking is a high-temperature short-time (HTST) method that inactivates enzymes and lowers microbial contamination.

Single-Screw Extruders

A cylindrical screw that revolves within a cylindrical barrel with a groove is the equipment's main component. It is composed of strong alloys or stainless steel that has been hardened to withstand frictional wear. The barrel's length to diameter ratio ranges from 2:1 to 25:1. The extruder's performance can be altered by varying the screw's pitch and diameter, the number of flights, and the distance between the flights and the barrel. A powerful electric motor with variable speed powers the screw, allowing it to pump food against the pressure inside the barrel. One of the primary elements affecting the extruder's performance is the screw speed.

Generally speaking, screw speeds range from 150 to 600 rpm, depending on the use. By increasing the screw's diameter and decreasing its pitch, employing a tapered barrel with a constant or decreasing screw pitch, and imposing limitations on the screw flights, the die creates the back pressure that causes compression in the extruder barrel. Die pressures for expanded snack foods range from 17,000 Pa to about 2000 Pa for low-viscosity formulations.

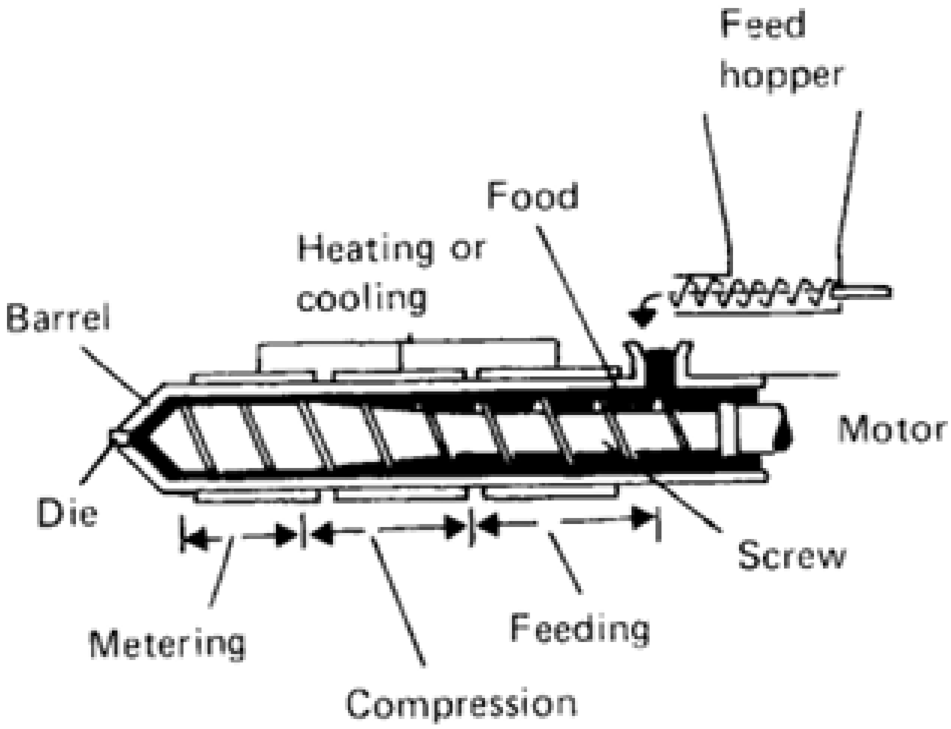

Fig. 6.6: Single Screw Extruder

In twin-screw extruders, the screws revolve inside a barrel bore that resembles a "figure of eight." The ratios of screw length to diameter range from 10:1 to 25:1. Extruders are categorized based on the screws' intermingling and rotational direction. Food processing is the most typical application for co-rotating intermeshing screws, which are self-wiping (the flights of one screw sweep food from the next screw). It is possible to modify the distance between the flights so that the material is first transported to the cooking area by the larger spaces, and then the plasticized mass is compressed by the smaller spaces prior to extrusion via a replaceable die.

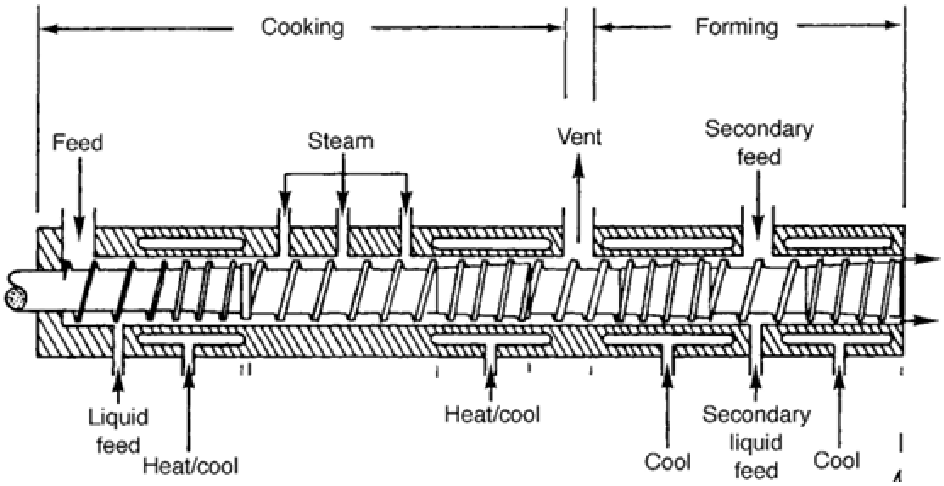

Fig. 6.7: Twin Screw Extruder

To improve the kneading motion, "kneading discs" can also be attached to the screws, allowing the product to travel through and between them. Frame describes their functioning properties. The following are some benefits of twin-screw extruders: The positive displacement action of the screws allows for adjustments in production rate, and the throughput is independent of feedrate. A single screw, on the other hand, needs to be filled with material in order to function properly. Compared to a single screw, the positive displacement also results in increased heat transfer rates and improved heat transfer management.

6.8 SUMMARY:

Because heat has preserving properties, such as destroying and inactivating enzymes, poisons, germs, etc., it is crucial for food preservation. Heat treatment is also crucial in food processing because it promotes consumer choice by making food more edible and tender and by adding desired textures, colors, flavors, and scents.

6.9 TECHNICAL TERMS:

Blanching, Twin Screw Extruder, Single Screw Extruder, Pasteurization, Temperature.

6.10. SELF-ASSESSMENT QUESTIONS:

1) Write about pasteurization.
2) What is Sterilization?
3) Describe the process of Extrusion.
4) Write about blanching and its advantages.

6.11 SUGGESTED READINGS:

1) Food Science 5th Edition by Potter, Norman N.
2) Food Science 3rd Edition by B. Shrilaxmi
3) Food Science Revised 2nd Edition by Sumati R. Mudambi, Shalini M. Rao and M.V. Rajagopal.

Dr. B. Babitha

LESSON-7

PROCESSING AND PRESERVATION BY COLD REFRIGERATION AND FREEZING, METHODS OF FREEZING, EFFECT ON QUALITY OF FOODS

7.0 OBJECTIVES:

After reading this chapter, students will be able to learn about

- The processing of food products and their preservation using low-temperature preservation techniques

STRUCTURE:

7.1 INTRODUCTION
7.2 PRESERVATION BY COLD REFRIGERATION AND FREEZING
7.3 METHODS OF FREEZING
7.4 EFFECT ON QUALITY OF FOODS
7.5 SUMMARY
7.6 TECHNICAL TERMS
7.7 SELF-ASSESSMENT QUESTIONS
7.8 SUGGESTED READINGS

7.1 INTRODUCTION

To increase the shelf life of lightly processed foods, chilling and other low temperature freezing methods are frequently combined with other unit procedures like fermentation or pasteurization. When chilling and storage atmosphere composition control are used together, the preservation impact is higher than when each unit operation is used alone. Tropical, subtropical, and certain temperate fruits, for instance, experience chilling harm at 3–10ºC above their freezing point, proving that not all foods can be frozen.

Numerous mesophilic and thermophilic bacteria cannot grow at low temperatures. The primary microbiological issues with chilled and refrigerated foods include several bacteria that can develop during prolonged storage below 5ºC or as a result of any temperature increase (temperature abuse), leading to food poisoning. It was once believed that refrigerator temperatures would stop harmful bacteria from growing; however, it is now known that some species may either proliferate at these temperatures in enormous quantities or are so ferocious that ingesting just a small number of cells might result in poisoning. Aeromonas hydrophilia, Listeria species, Yersinia enterocolitica, some strains of *Bacillus cereus*, *Vibrio parahaemolyticus*, and enteropathogenic *Escherichia coli* are a few examples of these pathogens.

The range of chilled foods can be characterized by the class of microbial risk that they pose to consumers as follows:

Class 1 - foods containing raw or uncooked ingredients, such as salad or cheese as ready-to-eat (RTE) foods (also includes chill-stable raw foods, such as meat, fish, etc.)

Class 2 - products made from a mixture of cooked and low risk raw ingredients

Class 3 - cooked products that are then packaged

Class 4 products are those that are cooked after packaging, including ready-to-eat products for extended durability (REPFEDs) having a shelf life of 40+ days (the acronym is also used to mean refrigerated-pasteurized foods for extended durability).

7.2 PRESERVATION BY COLD REFRIGERATION AND FREEZING COLD REFRIGERATION

A reduction in temperature below the minimum necessary for microbial growth extends the generation time of microorganisms and, in effect, prevents or retards reproduction. This mechanism is described in detail in most microbiological texts. There are four broad categories of microorganisms, based on the temperature range for growth.

1) Thermophilic (minimum: 30–40ºC, optimum: 55–65ºC)
2) Mesophilic (minimum: 5–10ºC, optimum: 30–40ºC)
3) Psychrotrophic (minimum: 0–5ºC, optimum: 20–30ºC)
4) Psychrophilic (minimum: 0–5°C, optimum: 12–18ºC)

Equipment

Chilling equipment is classified by the method used to remove heat into

- Mechanical refrigerators
- Cryogenic systems.

Batch or continuous operation is possible with both types of equipment, but all should lower the temperature of the product as quickly as possible through the critical warm zone (50-10ºC) where maximum growth of micro-organisms occurs.

Mechanical Refrigerators

A cryogen is a refrigerant that changes phase by absorbing latent heat to cool the food. Cryogenic chillers use solid carbon dioxide, liquid carbon dioxide or liquid nitrogen. Solid carbon dioxide removes latent heat of sublimation (**352 kJ kg 1 at 78ºC),** and liquid cryogens remove latent heat of vaporisation (358 kJ kg 1 at 196ºC for liquid nitrogen; liquid carbon dioxide has a similar latent heat to the solid). The gas also absorbs sensible heat as it warms from 78ºC (CO2) or from 196ºC (liquid nitrogen) to give a total refrigerant effect of 565 kJ kg 1 and 690 kJ kg 1 respectively.

The evaporator, compressor, condenser, and expansion valve are the four main components of a mechanical refrigerator. Copper is commonly used in refrigerator components because of its low thermal conductivity, which permits rapid heat transfer rates and excellent thermal efficiency. Between the refrigerator's four components, a refrigerant alternates between the following states: liquid, gas, and liquid. The liquid refrigerant in the evaporator absorbs latent heat of vaporization and cools the frozen medium as it evaporates under lower pressure.

From the evaporator, refrigerant vapor travels to the compressor, which raises the pressure. After that, the vapor travels to the condenser, where it condenses and the high pressure is maintained. In order to resume the refrigeration cycle, the liquid goes through the expansion valve, which lowers the pressure.

The following are the key characteristics of refrigerants:

- A low boiling point and high latent heat of vaporisation
- A dense vapour to reduce the size of the compressor
- Low toxicity and non-flammable
- Low miscibility with oil in the compressor
- Low cost.

Although ammonia is poisonous, combustible, and causes corrosion in copper pipes, it has good heat transmission qualities and is not miscible with oil. Although carbon dioxide requires far higher operating pressures than ammonia, it is safer to use, for instance, on refrigerated ships because it is neither combustible nor harmful. All halogen refrigerants, often known as chlorofluorocarbons or CFCs, are non-flammable and non-toxic. They also have superior heat transfer qualities and are less expensive than other refrigerants.

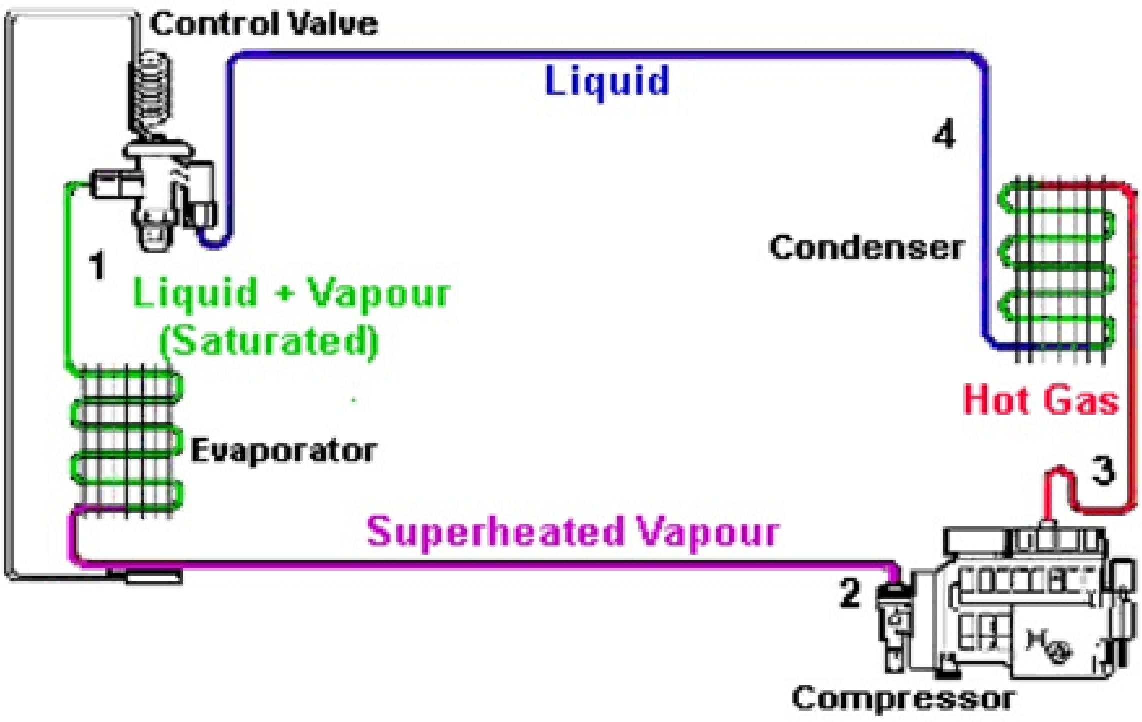

Fig. 7.2: Mechanical Refrigeration system

However, the Montreal Protocol has banned their usage as refrigerants worldwide due to their interaction with ozone in the earth's atmosphere and subsequent role as "greenhouse gases" in global warming. Partially halogenated CFCs (or HCFCs) are less environmentally harmful and existing HCFCs are being temporarily substituted for CFCs, but these too are to be phased out before the first decades of the new century. Newer, ozone-friendly HCFCs are being developed and are likely to become important refrigerants.

Cryogenic Chilling

The gas itself only contains 13% of the enthalpy from liquid carbon dioxide and 15% from the solid. This is in contrast to 52% in nitrogen gas, which means that sensible heat absorbed by the gas accounts for about half of the refrigerant effect of liquid nitrogen. Therefore, unlike liquid nitrogen, carbon dioxide does not require gas handling equipment to extract the majority of its heat capacity.

Asphyxia is the primary drawback of carbon dioxide and, to a lesser extent, nitrogen. There is therefore a maximum safe limit for operators of 0.5% CO2 by volume and excess carbon dioxide is removed from the processing area by an exhaust system to ensure operator safety, which incurs additional setup costs. Other hazards associated with liquefied gases include cold burns, frostbite and hypothermia after exposure to intense cold.

Either liquid carbon dioxide can be sprayed into the air to create thin particles of solid carbon dioxide "snow," which quickly sublimates to gas, or solid carbon dioxide can be used as "dry-ice" pellets. In combo bins, trays, cartons, or on conveyors, both kinds are placed on top of or combined with food. During transit or storage before additional processing, a tiny surplus of snow or pellets keeps the temperature down. This method of chilling can replace on-site cold stores, saving space and labor expenses if products are shipped right away in insulated containers or vehicles. Due to its lower cost and lack of the handling, storage, and operator safety issues that come with dry ice pellets, snow is taking their place.

For instance, minced meat was covered with dry-ice pellets when it was packed into containers in earlier meat processing methods. However, the uneven pellet distribution caused some meat to freeze and others to stay above 5ºC, which allowed bacteria to proliferate and produced inconsistent product temperatures for further processing. More recently, these issues have been resolved and quick, consistent cooling to 3–4ºC has been achieved by using snow horns to apply a thin layer of snow over minced beef as it is loaded into combo bins.

Both freezing and chilling processes involve liquid nitrogen. Usually, 90–200 kg of food are placed inside an insulated stainless steel cabinet with a liquid nitrogen injector and centrifugal fans for batch chilling. To produce a consistent drop in product temperature, the fans disperse the cold gas throughout the cabinet while the liquid nitrogen vaporizes instantly. The chiller is operated by a microprocessor and has several pre-programmed time/temperature cycles. The same pre-programmed cycle can be used regardless of the temperature of the incoming food since a food probe measures the product's temperature and the control system adjusts the cabinet's temperature as the food cools.

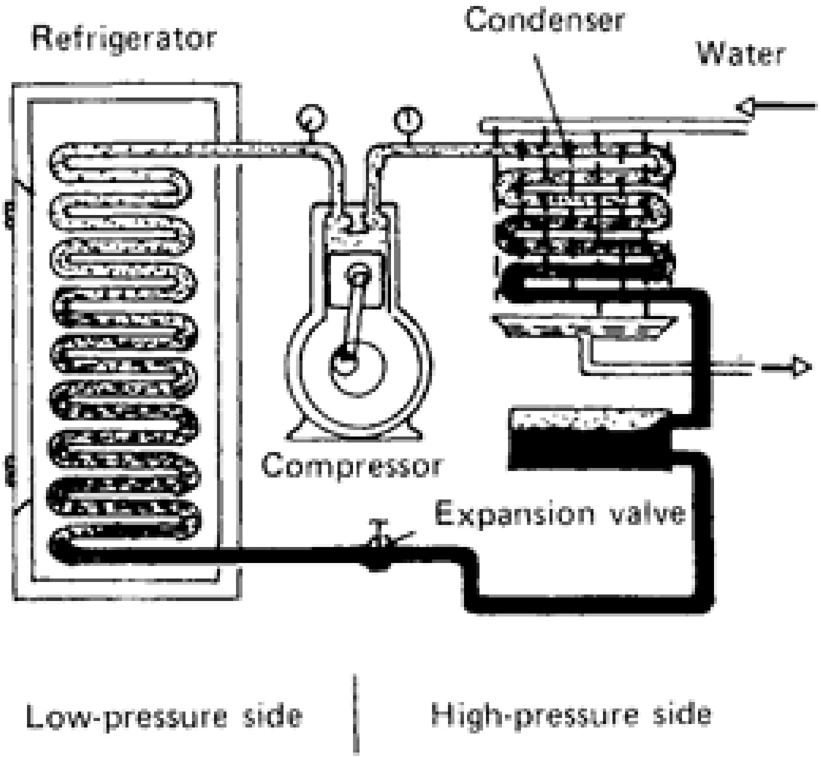

Fig. 7.3: Mechanical Refrigerator

Food is sent to an inclined, insulated, cylindrical barrel with a diameter of 80-120 cm and a length of 4-10 m, depending on the capacity, via a variable speed conveyor for continual cooling. The food is lifted and tumbled through the frigid nitrogen gas by internal flights while the barrel rotates slowly. A microprocessor regulates the temperature and gas flow rate, and the tumbling action keeps food particles from clinging to one another, resulting in a free-flowing product. Diced meat or veggies can be chilled in it until the third day. Liquid nitrogen tumblers with controlled temperatures are used to enhance the binding ability and texture of meat products that are mechanically produced.

The gentle tumbling action in a partial vacuum, cooled by nitrogen gas to 2ºC, solubilises proteins in poultry meat, which increases their binding capacity and water holding capacity, thus improving later forming and coating operations. An alternative design is a screw conveyor inside a 2.5 m long stainless steel housing, fitted with liquid carbon dioxide injection nozzles.

It is employed to remove heat from earlier processing steps or to firm meals prior to portioning or forming procedures. Additional uses for cryogenic cooling include the production of sausages, where heat produced during size reduction and mixing is eliminated by carbon dioxide snow, and cryogenic grinding, where the cryogen lowers dust levels, avoids dust explosions, and increases mill throughput. Cryogens help keep aromatic components from being lost during the grinding of spices. When making multi-layer cold dishes (such trifles and other sweets), the first layer of product is filled, and carbon dioxide is used to solidify the surface.

FREEZING

When a food's temperature is lowered below its freezing point, a part of the water changes states and forms ice crystals. This process is known as freezing. The water activity (aw) of the food is decreased by the immobilization of water to ice and the concentration of dissolved solutes in unfrozen water that results. Low temperatures, decreased water activity, and, in some cases, pre-treatment via blanching are the methods used to achieve preservation.

When proper freezing and storage techniques are used, foods' nutritional or sensory properties very little alter. The following are the main categories of commercially frozen foods:

- Whole or pureed fruits (strawberries, oranges, raspberries, and blackcurrants) or juice concentrates
- Vegetables, such as potatoes, spinach, sweet corn, peas, green beans, and sprouts
- Seafood (cod, plaice, shrimp, and crab meat) and fish fillets, such as fish fingers, fish cakes, or prepared dishes with a sauce
- Meats (poultry, lamb, and beef) in the form of carcasses, cubes or joints in boxes, and meat products (reformed steaks, beefburgers and sausages).
- Baked products, such as cakes, bread, and pies with meat and fruit prepared goods (full dinners, pizzas, desserts, ice cream, and cook-freeze dishes).

During freezing, sensible heat is first removed to lower the temperature of a food to the freezing point. In fresh foods, heat produced by respiration is also removed. This is termed the heat load, and is important in determining the correct size of freezing equipment for a particular production rate. Most foods contain a large proportion of water, which has a high specific heat (4200 J kg 1 K 1) and a high latent heat of crystallisation (335 kJ kg 1). A substantial amount of energy is therefore needed to remove latent heat, form ice crystals and hence to freeze foods. The latent heat of other components of the food (for example fats) must also be removed before they can solidify but in most foods these other components are present in smaller amounts and removal of a relatively small amount of heat is needed for crystallisation to take place.

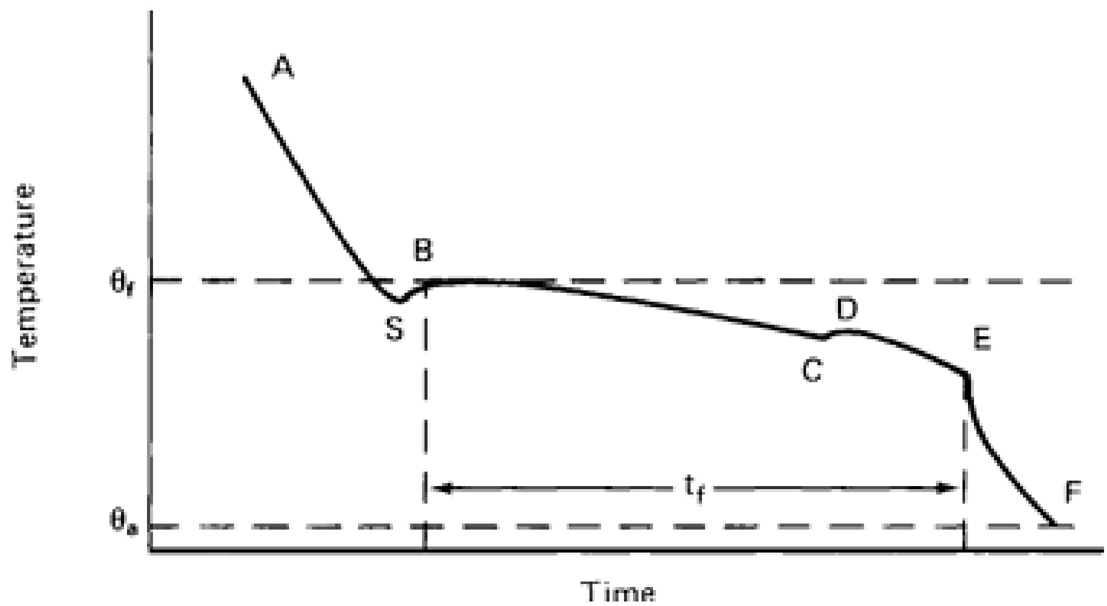

Fig. 7.4: Time-temperature data during freezing

AS

The food is cooled to below its freezing point of which, with the exception of pure water, is always below 0ºC. At point S the water remains liquid, although the temperature is below the freezing point. This phenomenon is known as supercooling and may be as much as 10ºC below the freezing point.

SB

The temperature rises rapidly to the freezing point as ice crystals begin to form and latent heat of crystallisation is released.

BC

Heat is removed from the food at the same rate as before, but it is latent heat being removed as ice forms and the temperature therefore remains almost constant. The freezing point is gradually depressed by the increase in solute concentration in the unfrozen liquor, and the temperature therefore falls slightly. It is during this stage that the major part of the ice is formed.

CD

One of the solutes becomes supersaturated and crystallises out. The latent heat of crystallisation is released and the temperature rises to the eutectic temperature for that solute.

DE

Crystallisation of water and solutes continues. The total time tf taken (the freezing plateau) is determined by the rate at which heat is removed.

EF

The temperature of the ice–water mixture falls to the temperature of the freezer. A proportion of the water remains unfrozen at the temperatures used in commercial freezing; the amount depends on the type and composition of the food and the temperature of storage. For example at a storage temperature of 20ºC the percentage of water frozen is 88% in lamb, 91% in fish and 93% in egg albumin.

Calculation of Freezing Time

During freezing, heat is conducted from the interior of a food to the surface and is removed by the freezing medium. The factors which influence the rate of heat transfer are:

- The thermal conductivity of the food
- The area of food available for heat transfer
- The distance that the heat must travel through the food (size of the pieces)
- The temperature difference between the food and the freezing medium • the insulating effect of the boundary film of air surrounding the food
- Packaging, if present, is an additional barrier to heat flow.

Although it is challenging to determine the freezing time exactly, two methods are used. While the nominal freezing time can be used as a measure of product damage because it ignores the initial conditions and the varying rates of cooling at different points on the food's surface, the effective freezing time1 measures the amount of time that food spends in a freezer and is used to calculate the throughput of a manufacturing process.

The calculation of freezing time is complicated for the following reasons:

- Differences in the initial temperature, size and shape of individual pieces of food
- Differences in the freezing point and the rate of ice crystal formation within different regions of a piece of food
- Changes in density, thermal conductivity, specific heat and thermal diffusivity with a reduction in temperature of the food.

Equipment

The required rate of freezing, the food's size, shape, and packaging requirements, batch or continuous operation, production scale, the variety of products to be processed, and lastly, capital and operating costs should all be taken into account when choosing freezing equipment. Freezers fall into the following general categories.

- Mechanical refrigerators, which evaporate and compress a refrigerant in a continuous cycle and use cooled air, cooled liquid or cooled surfaces to remove heat from foods
- Cryogenic freezers, which use solid or liquid carbon dioxide, liquid nitrogen (or until recently, liquid Freon) directly in contact with the food. An alternative classification, based on the rate of movement of the ice front is:
- Slow freezers and sharp freezers (0.2 cm h 1) including still-air freezers and cold stores
- Quick freezers (0.5–3cmh 1) including air-blast and plate freezers
- Rapid freezers (5–10 cm h 1) including fluidised-bed freezers
- Ultrarapid freezers (10–100 cm h 1), that is cryogenic freezers

7.3 METHODS OF FREEZING

Cooled-Air Freezing

Food is frozen at 20°C to 30°C in stationary (naturally circulated) air in chest freezers. Because of their low freezing rates (3–72 hours), which lead to poor process economics and a loss of product quality, chest freezers are not used for commercial freezing. Cold stores are used to store items that have been frozen using various techniques, to freeze cadaver meat, and to firm ice cream.

Cooled-Liquid Freezing

Packaged food is moved on a submerged mesh conveyor through a bath of chilled propylene glycol, brine, glycerol, or calcium chloride solution in immersion freezers. The liquid does not undergo a change of state during the freezing process, in contrast to cryogenic freezing. The technique has comparatively low capital costs and high heat transfer rates. Commercial applications include pre-freezing film-wrapped chicken prior to blast freezing and utilizing it for concentrated orange juice in laminated card-polyethylene cans**.**

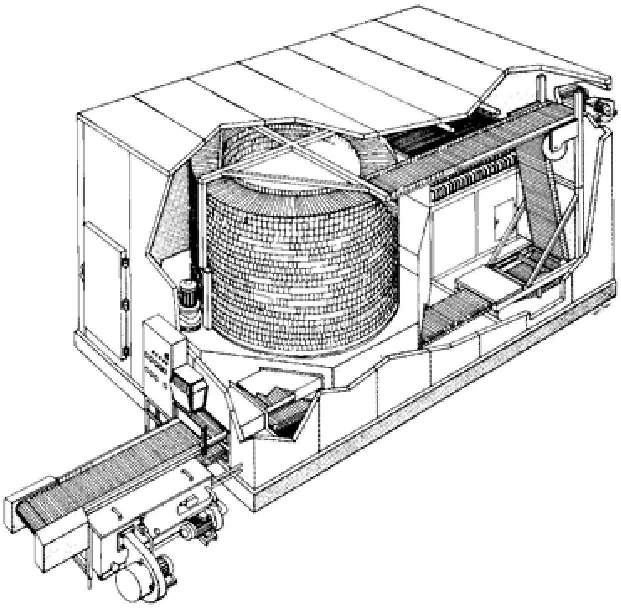

Fig. 7.5: Spiral Freezers

Cryogenic Freezing

As the heat from the freezing food is absorbed, the refrigerant (or cryogen) in these freezers changes states. Thus, the latent heat of vaporization or sublimation of the cryogen is provided by the heat from the meal. High heat transfer coefficients and quick freezing are produced by the cryogen's close contact with the food and its quick removal of heat from all of its surfaces. Liquid nitrogen and solid or liquid carbon dioxide are the two most often used refrigerants. Dichlorodifluoromethane (refrigerant 12 or Freon 12) was also previously used for sticky or fragile foods that stuck together in clumps (for example meat paste, shrimps, tomato slices), but its use has now been phased out under the Montreal Protocol, due to its effects on the earth’s ozone layer.

Technical performance for a specific product, cost and availability, safety, and environmental effect all influence the choice of refrigerant. Shorter product life cycles are becoming more and more common in the frozen food sector, which means that the quantity and kind of new items are changing more quickly. If the capital expenditure payback period is longer than the product life cycle, there is a serious commercial risk, unless the equipment is adaptable enough to handle new items. When opposed to mechanical systems, cryogenic freezers have two benefits: reduced capital costs and the ability to treat a variety of goods without requiring significant system modifications.

Both carbon dioxide and liquid nitrogen refrigerants are inert, colorless, and odorless. When food is sprayed with liquid nitrogen, the latent heat of vaporization required to create the gas absorbs 48% of the total freezing capacity (enthalpy). To make the best use of the freezing capacity, gas is recirculated because the cold gas contains the remaining 52% of the enthalpy. Although carbon dioxide has a lower enthalpy than liquid nitrogen, the sublimating solid provides the majority of the freezing capacity (85%), and the lower boiling point results in a less severe thermal shock.

Packaged or unpackaged food passes through a tunnel on a perforated belt in liquid-nitrogen freezers, where gaseous nitrogen and liquid-nitrogen sprays freeze it. Production rates range from 45 to 1550 kg per hour. Before food is taken out of the freezer, the temperature is either permitted to reach the proper storage temperature (between 18 and 30 degrees Celsius) or it is transferred to a mechanical freezer to finish the freezing process. Recirculation fans speed up heat transfer, and the use of gaseous nitrogen lessens thermal shock to the food.

7.4 EFFECT ON QUALITY OF FOODS

The primary impact of freezing on food quality is ice crystal development, which damages cells. Although these may be lost during preparation processes or deteriorate later during frozen storage, freezing has very little effect on colors, flavors, or nutritionally significant components. Because freezing can destabilize food emulsions and occasionally cause proteins to precipitate out of solution, frozen milk is not widely used. For baked goods to avoid staling and retrogradation during slow freezing and frozen storage, a significant amount of amylopectin must be present in the starch.

Animal and plant tissues differ significantly in their ability to withstand freezing damage. Because of their more pliable fibrous structure, meats split rather than shatter when frozen, and their texture is not significantly harmed. Ice crystals have the potential to harm the more rigid cell structure found in fruits and vegetables. The size of the crystals and, thus, the rate of heat transfer determine the degree of damage. Nonetheless, variations in the range and caliber of raw materials and the level of control over pre-freezing treatments both significantly impact food quality more than modifications brought about by properly executed freezing, frozen storage, and thawing processes.

7.5 SUMMARY

Generally speaking, the rate of microbiological and biochemical alterations decreases with decreasing frozen storage temperature. However, freezing and frozen storage have varying effects on microorganisms and do not inactivate enzymes. Microorganisms are more fatally affected by relatively high storage temperatures (between 4 and 10 degrees Celsius) than by lower temperatures (between 15 and 30 degrees Celsius). The resistance of various microorganisms to low temperatures also varies; bacterial spores (particularly Bacillus species and Clostridium species like Clostridium botulinum) are almost insensitive to low temperatures, while vegetative cells of yeasts, molds, and gram-negative bacteria (like coliforms and Salmonella species) are most readily destroyed. Gram-positive bacteria (like Staphylococcus aureus and Enterococci) and mold spores are more resilient to low temperatures.

7.6 TECHNICAL TERMS:

Crystallization, Freezing, Crystals, Cold Refrigeration, Refrigerants, Low temperature Preservation

7.7 SELF-ASSESSMENT QUESTIONS:

1) Write about refrigeration.
2) Write different methods of Freezing
3) Describe the process of mechanical refrigeration.

7.8 SUGGESTED READINGS:

1) Food Science 5th Edition by Potter, Norman N.
2) Food Science 3rd Edition by B. Shrilaxmi
3) Food Science Revised 2nd Edition by Sumati R. Mudambi, Shalini M. Rao and M.V. Rajagopal.

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LESSON-8

PROCESSING AND PRESERVATION BY DEHYDRATION AND CONCENTRATION -TYPES, METHODS AND THEIR SUITABILITY FOR DIFFERENT FOOD PRODUCTS

8.0 OBJECTIVES:

After reading this chapter, students will be able to learn about

- The processing of food products and their preservation using drying and concentration techniques.

STRUCTURE:

8.1 INTRODUCTION

The preservation of foods by drying is the time honored and most common method used by humankind and the food processing industry. The dehydration of food is one of the most important achievements in human history, making our species less dependent upon a daily food supply, even under adverse environmental conditions.

Drying in earlier times was done in the sun, but today many types of sophisticated equipment and methods are being used to dehydrate foods. In recent decades, considerable efforts have been made to understand some of the chemical and biochemical changes that occur during dehydration and to develop methods for preventing undesirable quality losses. Foods can be divided into three broad groups based on the value added through processing by drying.

In the case of cereals, legumes, and root crops, very little value is added per kilogram processed. More value per unit mass is added to foods such as vegetables, fruits, and fish; and considerably more to high-value crops such as spices, herbs, medicinal plants, nuts, bioactive materials, and enzymes.

Drying reduces the water activity, thus preserving foods by avoiding microbial growth and deteriorative chemical reactions. The effects of heating on the activity of microorganisms and enzymes are also important in the drying of foods. With foods to be preserved by drying, it is important to maximize microorganism and/or enzyme inactivation for preventing spoilage and enhanced safety, and to reduce the components causing the deterioration of dried foods. On the other hand, in the case of drying bacterial cultures, enzymes, or vitamins, minimum inactivation is required. Thus, detrimental effects of drying may be desirable or undesirable depending on the purpose of the drying process.

8.2 PRESERVATION BY DEHYDRATION

The terms dried and dehydrated are not synonymous. The US Department of Agriculture lists dehydrated foods as those with no more than 2.5% water (dry basis). The concept of bound and free water has been developed from drying principles, and it is important for dried products for their stability during processing and storage. A product containing no water is termed bone-dry.

Water in foods exists in different forms or states. Water in foods having properties different from those of pure water can be defined as bound water. In the literature different forms of bound water are defined, e.g., unfreezable, immobile, monolayer, and non-solvent water. However, the fraction of bound water depends on the definition and measurement techniques. The binding energy of different states of bound water affects the drying process, since it requires more energy to remove bound water than free water.

Equilibrium in the drying system is the ultimate endpoint for the process. Water activity is commonly used to estimate the equilibrium point in thermal and osmotic drying processes. In mechanical dewatering, the magnitude of the applied force and rheological properties of the foods affect the equilibrium point. Generally, meat, fish, and dairy products are dehydrated to a moisture content of 3% or less; vegetable products usually to 5%; and cereal products frequently to as much as 12%.

A maximum moisture level is usually established for each dried product separately, based on desired acceptable quality after drying and during storage. Different attributes of quality can be targeted; thus, the end point should be determined from all aspects, such as safety first and then consumer acceptance.

METHODS OF DRYING

Drying processes can be broadly classified, based on the water removing method applied as below

- Thermal drying,

- Osmotic dehydration
- Mechanical dewatering.

In thermal drying, a gaseous or void medium is used to remove water from the material.

Thermal drying can be divided into three types:

a) Air drying,

b) Low-air-environment drying, and

c) Modified-atmosphere drying.

In osmotic dehydration, a solvent or solution is applied to remove water, whereas in mechanical dewatering, physical force is used to remove water. Consideration should be given to many factors before selecting a drying process.

These factors include

a) The type of product to be dried,

b) Desired properties of the finished product,

c) Allowable temperature tolerance,

d) The product's susceptibility to heat,

e) Pretreatments required,

f) Capital and processing cost

g) Environmental factors.

There is no single best technique for drying of all products

Sun Drying

Formerly, sun drying was the only method used for drying food. The main disadvantage is the contamination and product loss by insects and birds. Where the climate is not particularly suitable for air drying or better quality is desired, mechanical air-drying is mainly used. Today, solar and mechanical air-drying is widely used commercially.

Solar Drying

In solar drying, radiation energy from the sun is used. Solar drying is a non-polluting process and uses renewable energy. Moreover, it is an abundant energy source that cannot be monopolized. Solar drying has several drawbacks, however, and these limit its use in large-scale production. These are the need for large areas of space and for high labor inputs, the difficulty in controlling the rate of drying, and insect infestation and microbial contamination. More options in designing are now available in the literature.

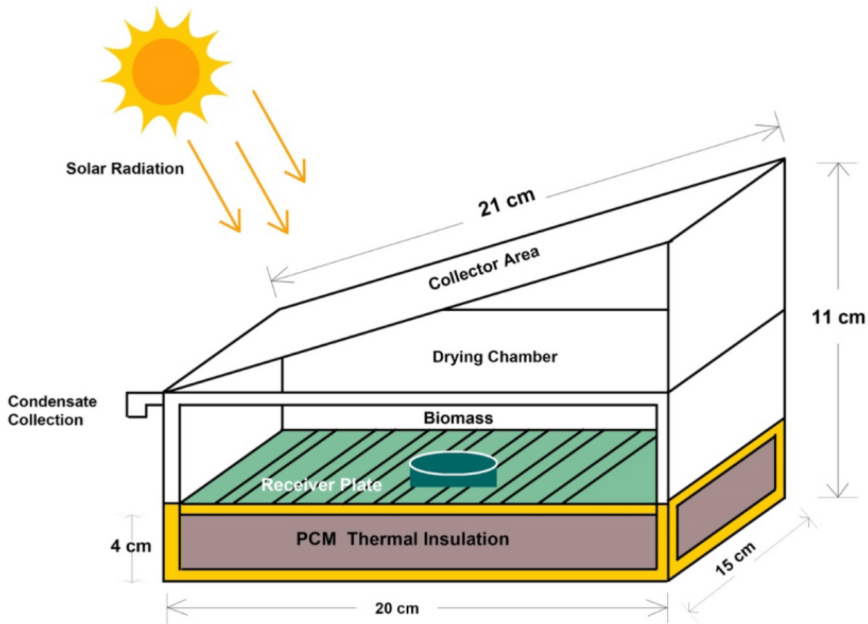

Fig. 8.1: Solar drier

Convection Air-Drying

Cabinet and bed-type dryers (i.e., kiln, tray, truck tray, rotary flow conveyor, and tunnel) fall into the first generation. This is the simplest drying technique, taking place in an enclosed and heated chamber. The drying medium, hot air, is allowed to pass over the product, which has been placed in open trays. Convection drying is often a continuous process and is most often used for products that are relatively low in value.

Fig. 8.2: Cabinet Drier

Air-drying is usually accomplished by passing air at regulated temperature and humidity over or through the food in a dryer. Factors affecting the rates of drying are temperature, humidity, air velocity and distribution pattern, air exchange, product geometry and characteristics, and thickness. The sample is usually placed on mesh trays in one layer or in a bulk bed or hangs from a string for better air circulation. The air circulation can be horizontal or vertical to the layer or bed. The structure and composition, such as fat content, of a product affects the drying rate. In general, the hotter the air temperature, the faster the drying rate; and similarly, the higher the velocity, the higher the drying rate.

Lower air humidity causes a higher drying rate. The relative humidity (a measure of dryness) falls when air temperature is raised. The dryer must expel air to get rid of moisture, thereby allowing new, lower-humidity air to enter the system. However, this process causes heat loss from the dryer. In many cases, two or multistage dryers are used, with different conditions, e.g., initial drying at 90°C and then the second or final stage at 60°C. Recirculating exhaust air in dryers is popular because of energy conservation and its effect on grain quality.

Spray-Drying

Spray-drying is used to remove water from a free-flowing liquid mixture, thus transforming it into a powder product. The fluid to be dried is first atomized by pumping it through either a nozzle or a rotary atomizer, thus forming small droplets with large surface areas. The droplets immediately come into contact with a hot drying gas, usually air. The liquid is very rapidly evaporated, thus minimizing contact time and heat damage.

Disadvantages include the size of the equipment required to achieve drying is very large, and very oily materials might require special preparation to remove excessive levels of fat before atomization. Ultrasonication in the chamber can be used instead of complex atomization to produce small-diameter droplets in spray-drying.

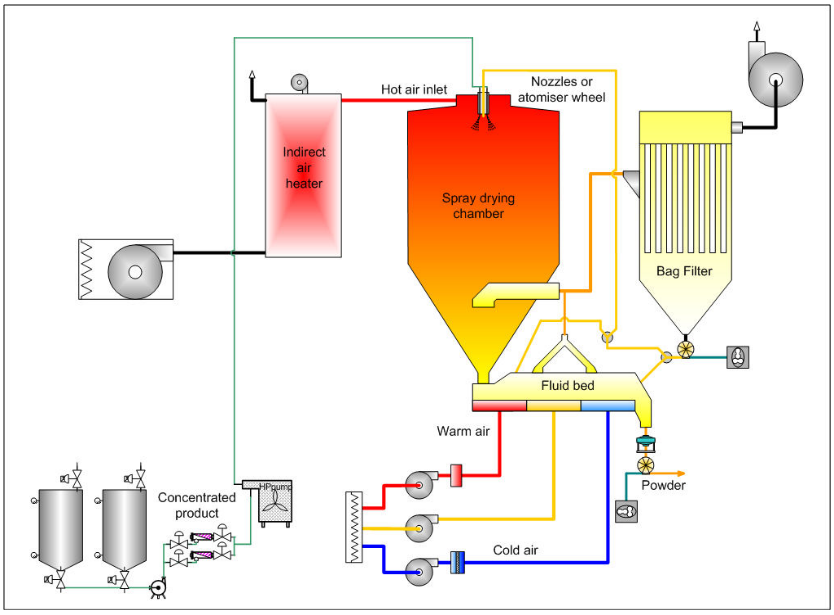

Fig. 8.3: Spray Drying Mechanism

Fluidized Bed Drying

This technique involves movement of particulate matter in an upward-flowing gas stream, usually hot air. Fluidization mobilizes the solid particulates, thus creating turbulences on the solid surfaces, which increases drying rate. The hot gas is introduced into the bottom of a preloaded cylindrical bed and exits at the top. In some cases, a vibratory mechanism is used to increase the contact of the product with the hot gas.

Fluidized bed drying is usually carried out as a batch process and requires relatively small, uniform, and discrete particles that can be readily fluidized. The main advantages of fluidized bed drying are uniform temperature and high drying rates, thus less thermal damage. A rotating chamber is also used with a fluidized bed, thus increasing centrifugal force to further increase the drying rate and mixing. The use of a solid carrier, such as sea sand and wheat bran, could be used to prevent the biomaterial from deteriorating due to thermal shock.

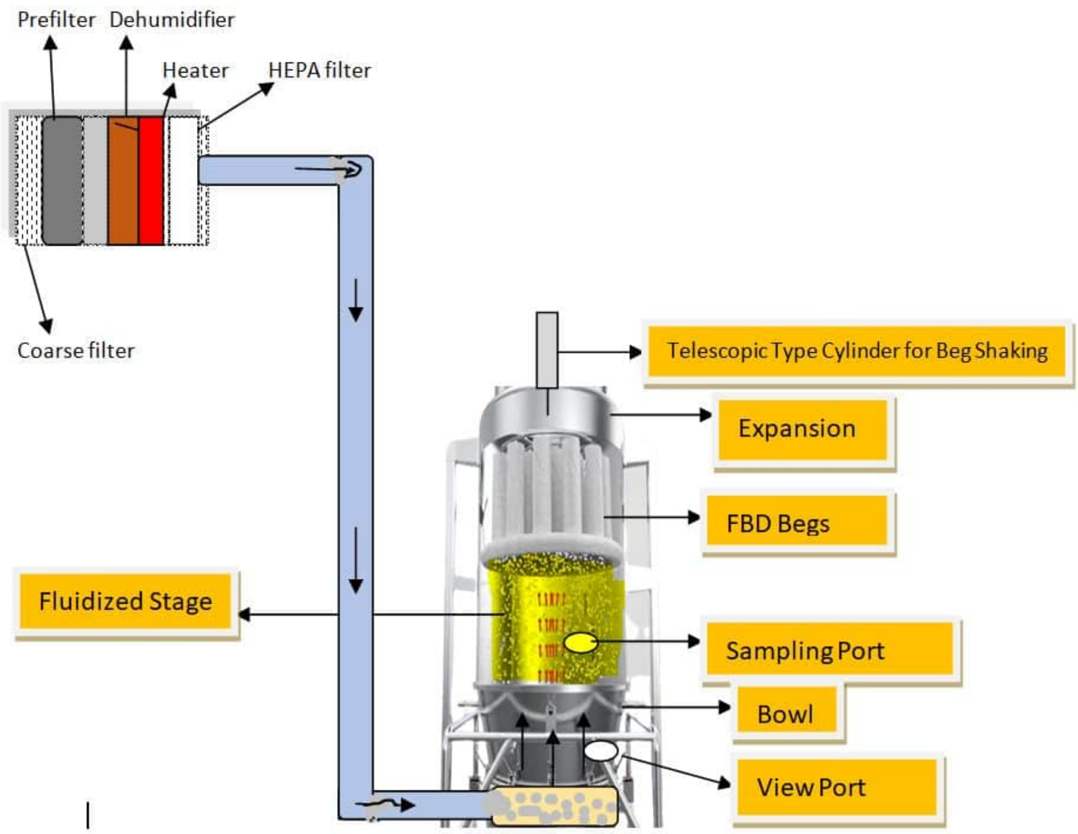

Fig. 8.5: Fluidized Bed Dryer

Vacuum-Drying

Vacuum-drying of food involves subjecting it to a low pressure and a heating source. The vacuum allows the water to vaporize at a lower temperature than at atmospheric conditions; thus, foods can be dried without exposure to high temperatures. In addition, the absence of air during drying diminishes oxidation reactions. In general, the color, texture, and flavor of vacuum-dried products are improved compared to air-dried. In some cases the product is comparable to the quality of freeze-dried.

Freeze-Drying

In freeze-drying, the material that has been frozen is subject to a pressure below the triple point (at 0°C, a pressure of 610 Pa) and heated to cause ice sublimation to vapor. This method is usually used for high-quality dried products, which contain heat-sensitive components such as vitamins, antibiotics, and microbial cultures.

The virtual absence of air and low temperature prevent deterioration due to oxidation or chemical modification of the product. It also gives very porous products, which results in a high rehydration rate. However, freeze-drying is a slow and expensive process. The long processing time requires additional energy to run the compressor and refrigeration units, which makes the process very expensive for commercial use.

8.3 PRESERVATION BY CONCENTRATION:

Concentration process is usually employed as a pretreatment to reduce the initial moisture content of different foods like milk, tea, or coffee prior to their final dehydration in a spray or freeze dryer. It can be used to reduce the bulk by freezing or by sterilization, such as frozen orange juice or evaporated milk. It could be used as a preservation method in its own right, like maple syrup, which is resistant to deterioration after concentration.

Water activity, pH, and temperature are the main parameters that have a direct impact on the growth of microorganisms; thus, aw and pH are two of the most important parameters for food preservation. Concentration of foods can broadly be of three types: by application of heat, i.e., thermal concentration; by removal of heat, i.e., freeze concentration; and by using membranes. The methods of concentration are discussed below.

Thermal Concentration

Thermal concentration means increasing the total solids content of the food by evaporation of water using heat. It is a more energy-consuming process than other concentration methods such as membrane concentration and freeze concentration. However, the degree of concentration achieved is higher. During thermal evaporation, food is boiled, which is achieved by the transfer of sensible heat from an energy source, i.e., steam, to the food. Then water gets evaporated in the form of bubbles by applying latent heat of vaporization. For calculation of degree of concentration, energy consumption, and processing times in an evaporator, heat and mass balances are calculated. Mass balance is defined as the feed mass entering the evaporator equaling the mass of product and vapor removed from the evaporator.

As the concentration process increases the solids content of a food, it preserves the food by reducing its water activity. During concentration microbial destruction occurs, which is mainly dependent on temperature. Concentration at 100ºC or above gives a preservative effect, as almost all pathogenic microorganisms get killed but not all the spores. Thermal evaporation because of the reduction in water activity improves microbial quality of foods.

On the other hand, when concentration is done under vacuum; many bacterial spores not only survive but also multiply. Applications of thermal concentration in the food industry include concentration of fruit juices; concentrated milk, lactose, and whey; sugar syrups; and vegetables to produce vegetable juices and purees.

Freeze Concentration

The freeze concentration process is used to overcome the two important limitations of thermal concentration, which are volatile component loss (flavors) and product quality degradation due to heat. It has primarily been used where quality considerations are important and important volatile components are to be retained, as in the concentration of beer and wines (where flavors and alcohol are to be preserved) and the concentration of coffee before freeze-drying (where it is important to retain flavor).

This process crystallizes water to ice as a primary step, followed by the removal of those ice crystals formed during freezing, followed by washing columns or mechanical separation techniques. In freeze concentration, a preservative effect similar to thermal concentration is attained by reducing the water activity of the food without using heat.

As a result, sensory characteristics and nutritional properties improved, which is not the case with thermally concentrated foods. This process is slower than conventional and membrane concentration processes. The high capital investment, combined with high costs due to refrigeration, results in high production costs for freeze-concentrated foods. Here, the degree of concentration is lower than thermal concentration but higher than membrane processes.

Concentration using Membranes

Conventional evaporation, in its variant forms, is the most widely used, very common as well as cost-effective process to get higher concentration of liquid or semi liquid foods. The major limitation of this process includes destruction of sensorial attributes and nutritional properties due to higher processing duration at higher temperatures. Although some of these changes can be reduced during well-known “multi effect vacuum evaporation” which reduces the operational temperature in each effect, yet it is neither suitable for heat sensitive products nor able to arrest the losses of typical volatile components.

Concentration of liquid foods is a helpful method of reducing weight or volume, thus the loss in packaging, storage, and transportation were found to be lesser. This method of concentrating the liquid food also helps in increasing the shelf-life of the food product by decreasing the water activity, increasing the acidity or decreasing the pH and the concentrated liquid food has a very good rehydrating property. Apart from this it also helps increase the product stability for storage with minimal changes in its organoleptic properties and nutritional value. Other reasons for concentration of liquid foods are because of the capability to produce shelf-stable foods that can be stored without refrigeration at room temperature, it improves the availability of some nutrients and helps destroy anti-nutritional factors. The availability of the seasonal fruits and vegetables can be made available in processed form throughout the year by concentrating the liquid food such as mango and tomato which has a very good demand in the market for human consumption.

The concentration of liquid foods is done by removal of water content from the initial liquid food that gets condensed to give a concentrated final product with lesser water activity. · As the liquid food is concentrated, it helps improve the product stability for a longer period of time and can be stored at room temperature without refrigeration. ·

The process of evaporation involved in concentrating the liquid food consists of removal of water to reduce the weight and volume of the final product and helps in ease of transportation, reduce storage space and packaging. Concentrating the liquid food is the most convenient way of extending the shelf life of foods by removing water or by destroying enzymes and microorganisms, responsible for food spoilage. Removal of water helps in increasing the solid content, reduces the water activity and enhances the shelf life of the food product and the concentrated liquid food has a very good rehydrating capacity. The rate of evaporation is governed by both the rate of heat transfer into the food and the removal of water.

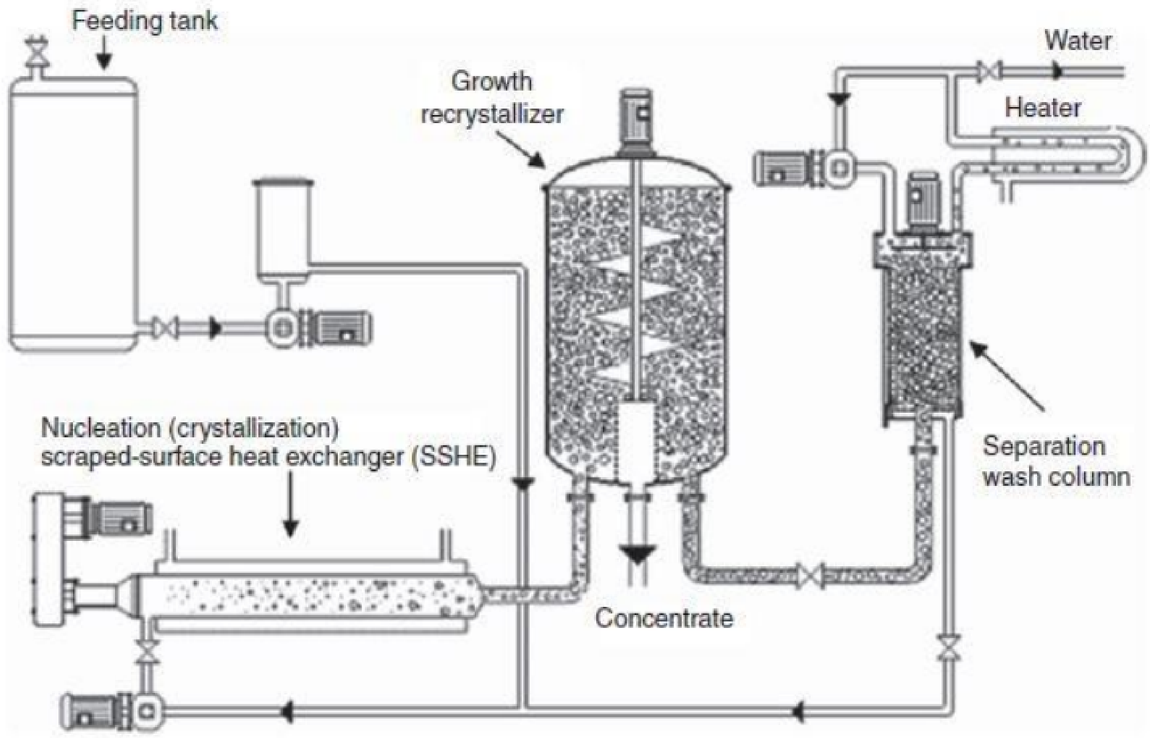

Fig. 8.6: Freeze Concentration System

The limitations of classical evaporation are overcome in freeze concentration, another concentration process that removes water via a sublimation process and results in better quality products. This process is considered efficient for highly valuable products only, not for the range of common products, as it is neither easy nor cheaper than the other two concentration processes.

8.4 METHODS AND SUITABILITY FOR DIFFERENT METHODS

Food preservation started long back in ancient times. Cooling, freezing, fermentation, sun-drying, etc., are few age-old food preservation techniques. With the advent of technology, modern methods of food preservation were developed. Chemicals and other natural substances were used for preservation. These substances are known as preservatives.

Salt and edible oils are two main preservatives which are used since ages to prevent microbial growth. This is why we add extra oil to pickles. Preservation by salt is known as salting. Salting helps to preserve fruits for a long term. Meats and fishes can also be preserved by salting. Other synthetic preservatives include vinegar, sodium benzoate, sodium metabisulphite, etc. Sugar is another common preservative used in jams and jellies. Sugar is good moisture absorbent. By reducing moisture content, it restrains microbial growth.

Boiling and refrigeration prevent around 70 percent of microbial growth. Boiling kills the microorganisms that cannot tolerate extreme temperatures. Thus, it helps in food preservation. Refrigerators have very low temperatures. Since microbes do not get the optimum temperature they need for growth, their growth is inhibited. Pasteurization developed by Louis Pasteur is used until today to preserve milk. Smoking prevents dehydration in fish and meat and thus prevents spoilage. The wood smoke contains a large number of anti-microbial compounds that slow the rancidity of animal fats. The food contents are sealed in an airtight container at high temperatures. Meat, fish, fruits are preserved by canning. Sterilization is carried out to remove microbes from food. For eg. Milk sterilization at 100°C kills the microbes.

Dehydration:

It is the process of removal of water from food. It is the simplest method and prevents food spoilage by removing water. Lyophilization is the process of freezing and dehydration of the frozen product under vacuum. Radiation is also known as cold sterilization. The UV rays, X rays, gamma rays kill all the unwanted microbes present in food.

8.5 SUMMARY:

Food preservation provides enhanced food security. It gives access to various foods throughout the year, not just seasonally. Many preservation methods retain most of the food's original nutritional value. People can save a lot of money by preserving food because it cuts down on food waste and lets them buy in bulk and save it for later use. Food preservation reduces the need to constantly grow and transport fresh food, lowering the carbon footprint of nutrition usage.

8.6 TECHNICAL TERMS:

Evaporation, Drying, Concentration, Feeding, Crystallization, Spray Drying, Vacuum Drying.

8.7 SELF-ASSESSMENT QUESTIONS:

1) What is evaporation?
2) Describe the methods of concentration in foods.
3) Write about the freeze-drying process.

8.8 SUGGESTED READINGS:

1) Food Science 5th Edition by Potter, Norman N.
2) Food Science 3rd Edition by B. Shrilaxmi
3) Food Science Revised 2nd Edition by Sumati R. Mudambi, Shalini M. Rao and M.V. Rajagopal.

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LESSON-9

PROCESSING AND PRESERVATION BY FERMENTATION

9.0 OBJECTIVES:

After going through this lesson students will understand

- Types of fermentation
- Various factors influencing the process of fermentation
- Benefits of fermentation

STRUCTURE:

9.1 INTRODUCTION

Fermentation is one of the most ancient and most important food processing technologies. Desirable microorganisms produce various fermented products. Raw foods are processed for many different reasons. Many fermented products are preserved with extension of shelf life. In addition to being more shelf-stable products and removal of anti-nutritional components, all fermented foods have aroma and flavour that result directly or indirectly from the fermenting microorganisms with altering chemical characteristics of the food, increasing vitamin content, increasing digestibility of the raw materials, and reducing toxicity of some foods.

9.2 TYPES OF FERMENTATION

Fermentation is the metabolic process in which carbohydrates and related compounds are oxidized with the release of energy in the absence of any external electron acceptors. The final electron acceptors are organic compounds produced directly from the breakdown of the carbohydrates. Some of the foods produced from fermentation of raw materials are pickles, olives, sausages, bread, cheese, cocoa, soy sauce, sauerkraut, pickles, beer, wine, and others.

1. Lactic acid homofermentation

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Lactic acid}}{2CH_3CHOHCOOH}$$

2. Lactic acid heterofermentation

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + H_2O \rightarrow \underset{\text{Lactic acid}}{2CH_3CHOHCOOH} + \underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Ethyl alcohol}}{C_2H_5OH} + 2CO_2 + 2H_2$$

3. Propionic acid fermentation

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Lactic acid}}{2CH_3CHOHCOOH} \rightarrow \underset{\text{Propionic acid}}{2CH_3CH_2COOH} + \underset{\text{Acetic acid}}{CH_3COOH} + CO_2 + H_2O$$

4. Diacetyl and 2,3-butylene glycol fermentation

$$\underset{\text{Citric acid}}{CH_2COOHHOCOOH} \rightarrow \underset{\text{Pyruvic acid}}{2CH_3COCOOH} \rightarrow \underset{\text{Acetylmethylcarbinol}}{CH_3COCHOHCH_3} + 2CO_2$$

$$\underset{\text{Acetylmethylcarbinol}}{CH_3COCHOHCH_3} \xrightarrow{\text{Oxidized-2H}} \underset{\text{Diacetyl}}{CH_3COCOCH_3}$$

$$\underset{\text{Acetylmethylcarbinol}}{CH_3COCHOHCH_3} \xrightarrow{\text{Reduced +2H}} \underset{\text{2,3-Butylene glycol}}{CH_3CHOHCHOHCH_3}$$

5. Alcoholic fermentation

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2$$

6. Butyric acid fermentation

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Butyric acid}}{CH_3CH_2CH_2COOH}$$

Types of Fermentation

Most commercially useful fermentation may be classified as

- Solid state fermentation
- submerged fermentation

In solid state fermentation, the microorganisms grow on a moist solid food with little or no free water. Examples of this type of fermentation are mushroom cultivation, bread making, and processing of cocoa and tempeh.

Submerged fermentation may use dissolved substrate, for example, sugar solution or a solid substrate, suspended in a large amount of water to form slurry. Examples of submerged fermentation are pickling vegetables, yogurt, beer, and wine.

Solid state and submerged fermentation both may be subdivided into

- oxygen introduced aerobic process
- anaerobic process

Examples of aerobic fermentation include submerged culture citric acid production by *Aspergillus niger* and solid-state koji fermentation (used to produce soy sauce) by *Aspergillus oryzae*.

Fermented meat products, such as sausages and salami, are produced by solid state anaerobic fermentation utilizing acid forming bacteria, particularly *Lactobacillus*, *Pediococcus*, *Staphylococcus*, and *Micrococcus spp*. A submerged anaerobic fermentation occurs in yogurt making. Intrinsic and extrinsic factors are critical to fermentation process.

- A process in which chemical changes occur in an organic substrate through the action of enzymes produced by microorganisms.
- A metabolic process in which carbohydrates and related compounds are partially oxidized with release of energy in the absence of any external electron acceptors. Final electron acceptors are organic compounds produced directly from the breakdown of carbohydrates and only a small amount of energy is released.

When growth environment contains free sugars, yeasts produce alcohol, and lactic acid bacteria (LAB) produce organic acids. When growth environment lacks simple sugars but has polysaccharides, the latter is hydrolyzed by microbial extracellular enzymes to allow fermentation. Most bacteria lack amylase to break down the polysaccharides.

The following are examples of process providing simple sugar from polysaccharides: Addition of barley malt to beer brewing. Enzymes can be generated in germinating barley before fermenting micro organisms, such as fermentation of koji–*Aspergillus oryzae* produces enzymes to hydrolyze starch to glucose (this conversion is not a fermentation process) in soy sauce and further lactic fermenting microorganisms use this glucose. Nutrient molecules are transported through cytoplasmic membrane and use through metabolic pathways.

There are many types of transport proteins (permeases) in cytoplasmic membrane for carrying nutrient molecules from the outside into the cell (also remove many end products from cell into the environment). In general, small molecules, such as mono and disaccharides, aminoacids, and small peptides (up to 8-10 amino acids) are transported by specific active transport systems (such as permeases). The fatty acids dissolve and diffuse through the lipid bilayers. The cell is able to produce extracellular enzymes to hydrolyze large molecules into corresponding small molecules that are then transported by the transport systems. Some molecules can also be transported across membrane against the concentration gradient of substrates.

9.2.1 Fermented Foods

An Ancient Tradition Fermentation is one of the oldest forms of food preservation technologies in the world. Indigenous fermented foods such as bread, cheese, yogurt, sausage, wine, and beer have been prepared and consumed for thousands of years and are strongly linked to culture and tradition, especially in rural households and village communities. The first fermented foods consumed probably were fermented fruits. Hunter gatherers would have consumed fresh fruits but at times of scarcity would have eaten rotten and fermented fruits. Repeated consumption would have led to the development of the taste for fermented fruits. Bread making probably originated in Egypt over 3500 years ago. Several triangular loaves of bread have been found in ancient tombs. Fermentation of milk products was in practice in Babylon over 5000 years ago. China is thought to be the birth place of fermented vegetables and they produced fermented grain products.

Fermentation is a relatively efficient, low energy preservation process that increases the shelf life and decreases the need for refrigeration or other forms of food preservation technology. It is therefore a highly appropriate technique for use in developing countries and remote areas where access to sophisticated equipment is limited. Fermented foods are popular throughout the world and in some regions make a significant contribution to the diet of millions of individuals.

9.2.2 Factors Influencing Fermentation

Fermentation is influenced by various factors, including temperature, pH, nature, and composition of the medium, dissolved oxygen, dissolved carbon dioxide, operation system (such as batch, fed-batch, continuous), feeding with precursors, and mixing and shear rates in the fermenter. These factors can affect the rate of fermentation, the product spectrum and yield, the organoleptic properties of the product (such as appearance, taste, smell, and texture), the generation of toxins, nutritional quality, and other physicochemical properties. The formulation of fermentation medium affects the yield, rate, and product profile. The medium must provide the necessary amounts of carbon, nitrogen, trace elements, and micronutrients to microorganisms. Specific types of carbon and nitrogen sources may be required and the carbon: nitrogen ratio may have to be controlled. Some trace elements may have to be avoided; for example, minute amounts of iron reduce yields in citric acid production by *Aspergillus niger*. Additional factors, such as cost, availability, and batch-to-batch variability also affect the choice of medium.

9.2.3 Biological Agents Responsible for Food Fermentation

The most common groups of microorganisms involved in food fermentation are bacteria, yeasts, and molds. Microbial enzymes also play an important role in food fermentation. Some fermentation may require only a single species of micro organism to effect the desired chemical change. Most fermentation requires several microbial species, acting simultaneously and/or sequentially, to give a product with the desired properties, appearance, aroma, texture, and taste. Vinegar processing is a combined effort of yeast and acetic acid bacteria. The yeast convert sugars to alcohol, which is the substrate required by the *Acetobacter* to produce acetic acid through oxidation.

Each microorganism has its own preferences for growing conditions, which are set within narrow limits. A micro organism that initiates fermentation will grow there until its by-products inhibit further growth and activity. When microorganisms metabolize and grow, they release specific by products.

In food fermentation, microorganisms are classified in accordance with by products. The fermentation of milk to yogurt involves a specific group of bacteria called the lactic acid bacteria. This is a general name attributed to those bacteria that produce lactic acid as they grow. In general, growth is initiated by bacteria, followed by yeasts and then molds. There are definite reasons for this type of sequence. The smaller microorganisms multiply and take up nutrients from the surrounding area most rapidly. Bacteria are the smallest of microorganisms, followed by yeasts and molds. The smaller bacteria, such as *Leuconostoc* and *Streptococcus*, grow and ferment more rapidly than the other closely related fermenters and are therefore often the first species to colonize in a substrate. Bacteria

Several fermentative bacterial species are present in foods, the majority of which are concerned with food spoilage. Some of the bacterial species are fermentative and carry out different fermentation process. The most important bacteria in desirable food fermentation are the LAB that has the ability to produce lactic acid from carbohydrates. Other important bacteria, especially in the oxidation of foods, are the acetic acid-producing *Acetobacter spp.*

9.2.3.1 Lactic Acid Bacteria (LAB):

LAB group is broadly defined as all members of fermenting bacteria that produce lactic acid from hexoses and lack functional heme linked electron transport systems or cytochromes and have no Krebs cycle. LAB carry out their reactions in the conversion of carbohydrate to lactic acid, carbon dioxide, and other organic acids without the need for oxygen. The principal genera of LAB are *Lactobacillus, Lactococcus, Leuconostoc,* *Pediococcus*, and *Streptococcus*. In addition to these five genera, some other bacteria can also be considered as LAB, but they generally not fit the group: *Aerococcus, Corynebacterium, Enterococcus, Erysipelothrix, Eubacterium, Mycobacterium, Oenococcus, Peptostreptococcus, Propionibacterium, Tetragenococ cus, Vagococcus,* and *Weissella*.

LAB are a group of Gram-positive, non motile, non respiring, non spore-forming, catalase and oxidase negative rods or cocci; they need carbohydrate as a source of energy and produce lactic acid as the major end product of the fermentation of carbohydrates. Most of the lactic acid producers are aero tolerant anaerobes and they grow in the presence of small amounts of oxygen. Some LAB that takes up O_2 through the mediation of flavor protein oxidizes to produce hydrogen peroxide. LAB require amino acids, B-vitamins, and nucleic acid bases (purine and pyrimidine); some grow at high temperatures (as high as 45°C); and some grow at variable pH ranges, but mostly well at 4.0 - 4.5 (some at as low as 3.2 and some at as high as 9.6). Generation time of LAB ranges from 30 to 90 min. The lactic acid produced by LAB inhibits the growth of other bacteria that may decompose or spoil the food.

9.2.3.2 Enzymes

The changes that occur during fermentation of foods are the result of enzymatic activity. Enzymes are complex proteins produced by living microbial cells to carry out specific biochemical reactions. They are sensitive to changes in temperature, pH, moisture content, ionic strength, and concentrations of substrate and inhibitors. Each enzyme has requirements at which it will operate most efficiently.

Extremes of temperature and pH will denature the protein and destroy enzyme activity. Because they are so sensitive to heat and pH, enzyme reactions can easily be controlled by slight adjustments to temperature, pH, or other reaction conditions. In the food industry, enzymes have several roles, such as the liquefaction and saccharification of starch, the conversion of sugars, and the modification of proteins. Microbial enzymes play a role in the fermentation of foods. Coffee and tea are produced with the enzymatic fermentation.

9.3 FACTORS AFFECTING FERMENTATION

In desirable fermentation, the desired bacteria, yeasts, or molds start to multiply and grow on the substrate. This growth suppresses other microorganisms that may be either pathogenic or spoilage. The type of microorganisms present and the environmental conditions will determine the nature of the fermentation. By changing the external environmental conditions, microbial growth can be controlled to produce desirable products. A fermentation is influenced by numerous factors, including moisture, temperature, nature, and composition of medium, dissolved O_2 concentration, dissolved CO_2, operation system (such as batch, feed batch, and continuous), feed with precursors, mixing, pH, and inhibitors. Variation of these factors may affect the rate of fermentation, the product spectrum and yield, the organoleptic properties of the product (appearance, taste, smell, and texture), the generation of toxins, nutritional quality, and other physicochemical properties. By changing any of these factors, the activity of microorganisms with in foods can be controlled. Moisture, Water is essential for the growth and metabolism of microorganisms. If it is reduced or removed, cellular activity is decreased. There are free and bound water in foods. Bound water is present within the tissue and is vital to all the physiological processes within the cell and hydrate molecules. Free water exists in and around the tissues, and can be removed from microbial cells and foods. Free water is essential for the survival and metabolic activity of microorganisms. Therefore, by removing free water, the level of microbial activity can be controlled. The amount of water available for microorganisms is referred to as the water activity (aw).

Bacteria require more water than yeasts, which require more water than molds. Almost all microbial activities are inhibited below aw of 0.6. Most fungi, yeasts, and bacteria are inhibited below aw of 0.7, 0.8, and 0.9, respectively. Naturally, there are exceptions to these guidelines and several species of microorganism can grow outside these ranges. The water activity of foods can be changed by altering the amount of free water. There are several ways to achieve this: drying to remove water; freezing to change the state of water from liquid to solid; and increasing or decreasing the concentration of solutes by adding salt or sugar or other hydrophilic compounds.

9.3.1 Oxidation-Reduction Potential

Oxidation-reduction potential (ORP) is the ratio of total oxidizing (electron accepting) power to the total reducing (electron-giving) power of the substrate ORP indicates concentration of reduced or oxidized substrates. The electron transfer between substrates creates potential differences (Eh). The Eh is measured in millivolts (mV). The more oxidized the substrates and the higher the Eh (+mV), the more reducing the substrates and the lower the Eh (mV). Microorganisms that grow at high Eh (+mV) in the presence of O_2 is called aerobic, at low Eh (mV) in the absence of O_2 is called anaerobic, at high or low Eh (+ or mV) in the presence or absence of O_2 is called facultative anaerobic, at relatively low Eh in the presence of lower amount of O_2 is called micro aerophilic, and at low Eh (mV) in the absence or presence of O_2 (without its use) is called aerotolerant anaerobic (fermentative). ORP of a food can be highly variable among foods depending on changes in the pH, microbial growth, packaging, partial pressure of O_2 in the storage environment, buffering (poising) capacity, and ingredients and composition (protein, ascorbic acid, reducing sugars, oxidation level of cations, etc.). The Eh is measured at pH 7.0. The ORP can be controlled by vacuum packaging, skin-tight packaging, canning, and antioxidants. Controlling the availability of free O2 (that change ORP) is one means of controlling microbial activity within a food. It determines the type and amount of biological product formation, the amount of substrate consumed, and the energy released from the reaction.

9.3.2 Temperature

Temperature affects the growth and activity of microorganisms. At high temperatures, microorganisms are destroyed, while at low temperatures, their rate of activity is decreased or suspended. Microorganisms can be classified into different groups according to their growth temperature preference:

- Psychrophilic
- Mesophilic
- Thermophilic

Each microorganism has an optimum, maximum and minimum growth temperature. Microorganisms show higher metabolic activity at optimum growth temperature.

9.3.3 Nutritional Requirements

The majority of microorganisms depend on nutrients for both energy and growth. Microorganisms vary in their specificity toward different substrates. Sources of energy vary from simple sugars to complex carbohydrates and proteins. The energy requirements of microorganisms are very high. Limiting the amount of available substrate can reduce the growth of microorganisms.

9.3.4 Hydrogen Ion Concentration (pH)

The pH of a substrate is a measure of the hydrogen ion concentration. A food with a pH of 4.6 or less is termed a high acid or acid food and will not permit the growth of most bacterial cells. The optimum pH for most microorganisms is near the neutral (pH 7.0). Certain bacteria are acid tolerant and will survive at reduced pH levels. Acid tolerant bacteria include *Lactobacillus* and *Streptococcus spp.*, which play a role in the fermentation of foods.

Molds and yeasts are usually acid tolerant and are therefore associated with spoilage of acidic foods. Microorganisms vary in their optimal pH requirements for growth. Yeasts can grow in the pH range of 4-6.5 and molds in the pH of 2-8.5, but molds grow well in an acid pH. The varied pH requirements of different groups of microorganisms are used to good effect in fermented foods. For instance, some group of microorganisms ferment sugars so that the pH becomes too low for their survival. The acidophilic microorganisms then take over and continue the reaction. The affinity for different pH can also be used to good effect to inhibit spoilage microorganisms.

9.3.5 Inhibitors

Many chemical compounds can inhibit the growth and activity of micro organisms. They prevent metabolism, denaturate protein, or cause physical damage on the cell. The production of substrates as part of the metabolic reaction can also inhibit microbial action.

9.4 BENEFITS AND LIMITATIONS OF FERMENTATION

In addition to the roles of fermentation in preservation and providing variety to the diet, there are further important consequences of fermentation. Several of the end product of food fermentation particularly acids and alcohols are inhibitory to the common pathogenic mircororganisms that may find their way in to food e.g. *Clostridium botulinum* cannot grow and produce toxin at pH values of 4.6 and below. Increasing the acidity of foods by fermentation is very common, e.g. yogurt, hard sausages and sauerkraut.

Fermented foods can be more nutritious than their unfermented counterpart. Microorganism are not only breakdown more complex compounds, but also are synthesize several complex vitamins and other growth factors. Riboflavin, vitamin B_{12} and precursor of vitamin C are produced by special fermentation processes.

Fermentation helps in liberating nutrients locked into plant structures and cells by indigestible materials. This is especially true in the case of certain grains and seeds. Moulds are rich in cellulose splitting enzymes; in addition, mould growth penetrates food structures by way of its mycelia. This alters texture and makes the structures more permeable to the cooking water as well as to human digestive juices.

Similar phenomena result from the enzymatic actions of yeasts and bacteria. Fermentation technology is not simple. To obtain balanced flavours fermentation processes must be controlled to balance the various types of microorganisms that may grow in foods. Sugar fermented by yeasts, such as *Saccharomyces ceresisiae* and *Saccharomyces ellipsoideus* yield ethyl alcohol and carbon dioxide. This is the basis of wine and beer production and the leavening of bread.

Alcohol from yeast fermented cider in the presence of oxygen will be further fermented by bacteria such as A*cetobacter act*i to acetic acid as in the reaction

$$C_2H_5OH + O_2 \xrightarrow{\textit{Acetobacter acti}} CH_3COOH + H_2O$$

This is the mechanism of vinegar production. Lactose fermented by *Streptococcus lactis* bacteria gives lactic acid which curdles milk to yield cottage cheese and curd from which other cheeses can be made.

Limitations

- Low scale production that requires high cost and high energy
- Possibilities of contamination.
- Natural variations over time
- The product is impure which needs further treatment
- the undesirable and unexpected end product
- The undesirable microbes grow and multiply and desirable microbes died.

9.5 SUMMARY:

Fermentation is the metabolic process in which carbohydrates and related compounds are oxidized with the release of energy in the absence of any external electron acceptors. Fermentation is a relatively efficient, low energy preservation process that increases the shelf life and decreases the need for refrigeration or other forms of food preservation technology. Fermentation is influenced by various factors, including temperature, pH, nature, and composition of the medium, dissolved oxygen, dissolved carbon dioxide, operation system (such as batch, fed-batch, continuous), feeding with precursors, and mixing and shear rates in the fermenter. Fermented foods can be more nutritious than their unfermented counterpart. Microorganism are not only breakdown more complex compounds, but also are synthesize several complex vitamins and other growth factors. Riboflavin, vitamin B_{12} and precursor of vitamin C are produced by special fermentation processes.

9.6 TECHNICAL TERMS:

Fermentation, lactic acid bacteria, fermented foods

9.7 SELF ASSESSMENT QUESTIONS:

1) Discuss about types of fermentation
2) Write an account on factors affecting the process of fermentation
3) Describe the benefits of fermentation

9.8 REFERENCE BOOKS:

1) B.Srilakshmi, Food science seventh edition.
2) Food Microbiology: Principles into Practice, First Edition. Osman Erkmen and T. Faruk Bozoglu. © 2016 John Wiley & Sons, Ltd. Published 2016 by John Wiley & Sons, Ltd.
3) https://microbenotes.com/fermentation/

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LESSON-10

PROCESSING AND PRESERVATION OF FERMENTED FOODS CEREAL AND PULSE PRODUCTS

10.0 OBJECTIVES:

After going through this lesson students will understand

- Fermented foods from cereals
- Health benefits of fermented cereal products
- Changes during fermentation process of bread
- Fermented foods from pulses

STRUCTURE:

10.1 INTRODUCTION

Fermented foods may be defined as foods which are processed through the activity of microorganisms. The weight of the microorganisms in the food is usually small, but their influence on the nature of the food, especially in terms of flavour and other organoleptic properties, is strong. In terms of this definition, mushrooms cannot properly be described as fermented foods as they form the bulk of the food and do not act on a substrate which is consumed along with the organism. quite the reverse, yeasts form a small proportion by weight on bread, and are responsible for the flavour of bread; hence bread is a fermented food.

- Fermentation serves as a means of preserving foods in a low cost approach, cheese keeps longer than the milk from which it is produced.
- The organoleptic properties of fermented foods are improved in comparison with the raw materials from which they are prepared. For e.g. cheese tastes very different from milk from which it is produced.
- Fermentation occasionally removes unwanted or harmful properties in the raw material; this process removes flatulence factors in soybeans, and reduces the poisonous cyanide content of cassava.
- The nutritive content of the food is improved in many foods by the presence of the microorganisms, so the yeasts in bread add to the nutritive quality of these foods.
- Fermentation reduces the cooking time of the food as in the case of fermented soybean products.
- Fermented foods are influenced by the nature of the substrate added and the organisms involved in the process of fermentation, the length of the fermentation and the treatment of the food during the processing.

10.2 FERMENTED FOOD FROM CEREALS

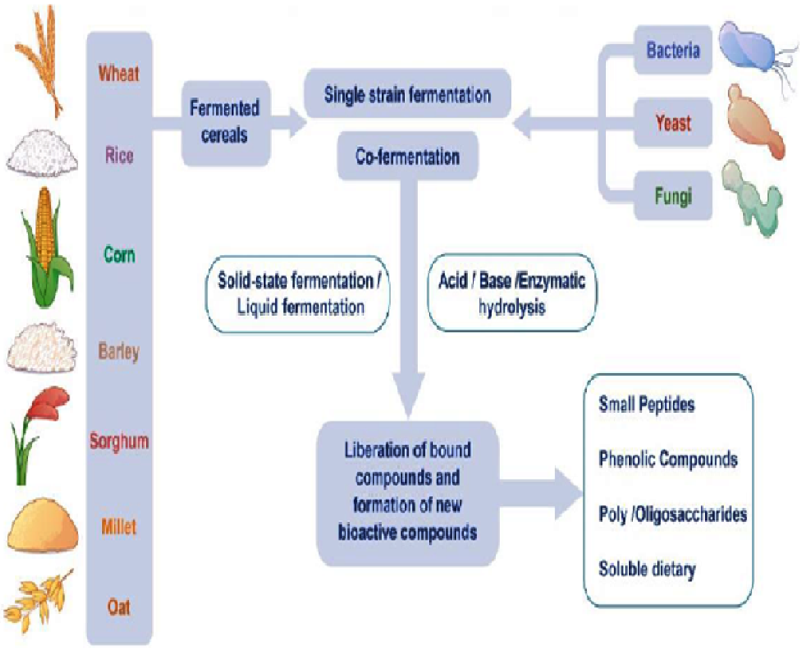
Cereals are essential sources of carbohydrates, proteins, minerals, fibers, and vitamins. Despite their drawbacks as deficiency in certain amino acids, lower protein content, presence of antinutrient compounds compared to products of animal origin or dairy foods, the fermented types of cereals are nutritionally superior to their native counterparts.

As plant based fermented cereal products are suitable for people with lactose intolerance, milk allergies, or people who follow a low lipid or vegan dietary pattern. They are also considered as novel probiotic release vehicles and potential functional foods.

GRAIN BASED FERMENTED FOODS IN INDIA

NAME	INGREDIENTS	STATE
Koozhu	*E. coracana* (ragi) (ragi) flour, boiled rice, non-fat yoghurt	Tamil Nadu
Pazhaiya soru	Rice, curd and salt	Tamil Nadu
Idli	Rice, black gram dhal, Table salt, fenugreek seeds	South Indian
Dosa	Rice, black gram dhal (either raw or parboiled rice), Table salt	South Indian
Adai dosa	Boiled rice, Bengal gram, red gram, black gram, green gram	South Indian
Kallappam	Boiled or raw rice, coconut toddy	South Indian
Dhokla	South Bengal gram dhal, rice and leafy vegetables	South Indian
Ambali	Ragi (Millet) flour and rice	Karnataka and Tamil Nadu
Jilebi	*Wheat, sugar and curd*	*South Indian*
Gulgule	Wheat flour and starter material Malera	Himanchal Pradesh
Seera	Wheat, sugar and ghee	Himanchal Pradesh
Chhuchipatra pitha	Par-boiled rice, black gram, coconut, sugar and curd	Orissa
Bhatura or indigenous bread	Wheat and starter material Khameer/Malera	Himanchal Pradesh
Kulcha	Wheat and the starter Khameer/Malera	Northern India
Chitou	Par-boiled rice and black gram	Orissa
Sel roti	Rice, banana, honey, ghee and spices	H.P and Sikkim
Manna	Wheat	Himanchal Pradesh
Kurdi	Wheat	North India
Aska, anarshe, aenkadu/askalu, patande	Rice	Himanchal Pradesh
Torani	Rice	Orissa
Aet, aktori, baari, babroo, bhatooru, chhura, mande/manna, malpude, tcung, shunali	Wheat flour	Himachal Pradesh
Chhangpa, doo, khawalag, marpinni/ marjag, tchog, thuktal	Roasted barley flour	Himachal Pradesh
Mangjangkori	Buck wheat bran	Himachal Pradesh
Endure pitha	Fermented batter of parboiled rice and black gram	Odisha
Sinki	Fermented raddish taproot	Nepal, Darjeeling, Sikkim and Northeast
Sez	Rice	Uttarakhand, Himachal Pradesh
Ragi hurihittu	Popped finger millet flour	North east
Akhone	Soybean	Khasi and Garo in Meghalaya.
Tiskori	Wheat bran	Himachal Pradesh
Sour rice	Raw rice	Assam, Bengal, and Odisha
Anarshe	Gluten-Colloid Type Fermented Food	Sikkim and Himalayan India
Uttapam	Rice and Urad Dahl	South India
Kinema	Soybeans	Darjeeling, Sikkim
Bari	Soybeans	Sikkim
Hawaizaar, hakhu mata/akhuni	Soybeans	Manipur
Wari	Black bean and soybean Uttar Pradesh	U.P
Masyaura	Black gram or green gram, Colocosia tuber, ashgourd or radish	Darjeeling hills and Sikkim
Bedvin roti	Black gram, opium seeds or walnut	H.P

Source: Rawat1 et al., Traditional Fermented Products of India International Journal of Current Microbiology and Applied Sciences Int.J.Curr.Microbiol.App.Sci (2018) 7(4): 1873-1883.



Release of Bioactive Compounds from Cereal Fermentation

Source: Jiayan Zhang et al., (2022) Recent developments in fermented cereals on nutritional constituents and potential health benefits. Foods 2022, 11, 2243.

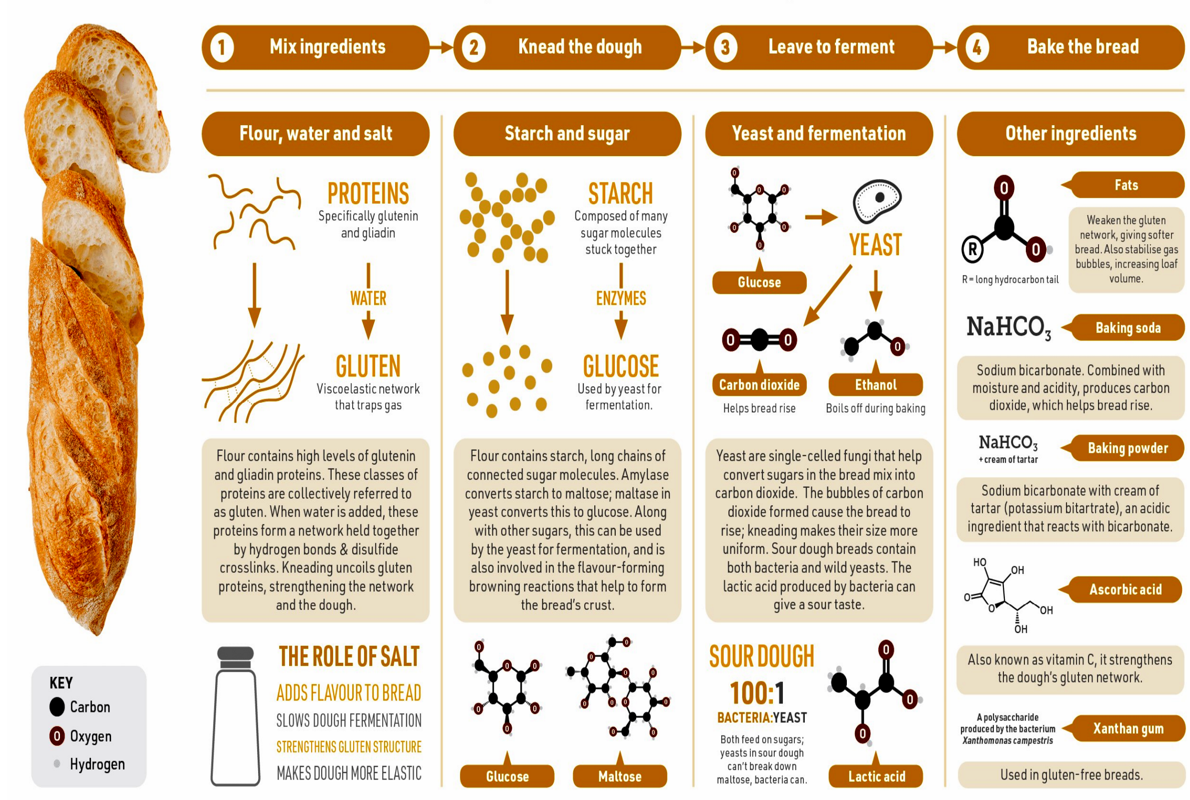
10.2.1 Bread Making

Wheat Bread has been known to man for many centuries. Today, bread supplies over half of the caloric intake of the world's population including a high proportion of the intake of Vitamins B and E. Bread therefore is a major food of the world.

The basic ingredients in bread making are flour, water, salt and yeasts. In modern bread making however a large number of other components and additives are used as knowledge of the baking process has grown. These components depend on the type of bread and on the practice and regulations operating in a country. They include "yeast food", sugar, and milk, eggs, shortening (fat) emulsifiers, antifungal agents, antioxidants, and enzymes, flavouring and enriching ingredients. The ingredients are mixed together to form dough which is then baked. Flour is the chief ingredient of bread and is produced by milling the grains of wheat, various species and varieties of which are known. For flour production most countries use *Triticum vulgare*.

A few countries use *Triticum durum*, but this yellow coloured variety is more familiarly used for semolina and macaroni in many countries. The chief constituents of flour are starch (70 %), protein (7-15 %), sugar (1 %) and lipids (1.0 %). In bread making from *Triticum vulgare* the bread making quality of the flour depends on the quality and quantity of its proteins.

Flour proteins are of two types. The first type, forming about 15 % of the total, is soluble in water and dilutes salt solutions, and is non dough forming. It consists of albumins, globulins, peptides, amino acids and enzymes. The remaining 85 % are insoluble in aqueous media and are responsible for dough formation. They are collectively known as gluten. It also contains lipids. Gluten has the unique property of forming an elastic structure when moistened with water. It forms the skeleton which holds the starch, yeasts, gases and other components of dough.



Process of Bread Making

Source: https://www.compoundchem.com/2016/01/13/bread/

Gluten can be easily extracted, by adding enough water to flour and kneading it into dough. After allowing the dough to stand for an hour the starch can be washed off under a running tap water leaving a tough, elastic, sticky and viscous material which is the gluten. Gluten is separable into an alcohol soluble fraction which forms one third of the total and known as gladilins and a fraction (2/3) that is not alcohol soluble and known as the glutenins. Gladilins are of lower molecular weight than glutenins; they are more extensible, but less, elastic than glutenins. Glutelins are soluble in acids and bases whereas gladenins are not. The latter will also complex with lipids, whereas glutelins do not.

“Hard” wheat with a high content of protein (over 12 %) is best for making bread because the high content of glutenins enables a firm skeleton for holding the gases released curing fermentation. “Soft” wheat with low protein contents (9-11 %) is best for making cakes. The yeasts used for baking are strains of *Saccharomyces cerevisiae*. The ideal properties of yeasts used in modern bakeries are as follows: ability to grow rapidly at room temperature of about 20-25°C; easy dispersability in water; ability to produce large amounts of CO_2 rather than alcohol in flour dough; good keeping quality i.e. ability to resist autolysis when stored at 20°C; ability to adapt rapidly to changing substrates such as are available to the yeasts during dough making high invertase and other enzyme activity to hydrolyze to higher glucofructans rapidly; ability to grow and synthesize enzymes and coenzymes under the anaerobic conditions of the dough; ability to resist the osmotic effect of salts and sugars in the dough; high competitiveness i.e. high yielding in terms of dry weight per unit of substrate used.

In general the "foods" contain a calcium salt, an ammonium salt and an oxidizing agent. The bivalent calcium ion has a beneficial strengthening effect on the colloidal structure of the wheat gluten. The ammonium is a nitrogen source for the yeast. The oxidizing agent strengthens gluten by its reaction with the protein's sulphydryl groups to provide cross links between protein molecules and thus enhances its ability to hold gases released during dough formation.

Oxidizing agents which have been used include iodates, bromates and peroxide. A commonly used yeast food has the following composition: calcium sulphate, 30 %, ammonium chloride, 9.4 %, sodium chloride, 35 %, potassium bromate, 0.3 %; starch (25.3 %) is used as a filler. Sugar is added: to provide carbon nourishment for the yeasts additional to the amount available in flour sugar; to sweeten the bread; to afford more rapid browning (through sugar caramelization) of the crust and hence greater moisture retention within the bread. Sugar is supplied by the use of sucrose, glucose corn syrups (regular and high fructose), depending on availability.

Animal and vegetable fats are added as shortenings in bread-making at about 3 % (w/w) of flour in order to yield increased loaf size; a more tender crumb; and enhanced slicing properties Butter is used only in the most expensive breads; lard (fat from pork) may be used, but vegetable fats especially soy bean oil, because of its most assured supply, is now common. Emulsifiers are used in combination with shortening and ensure a better distribution of the latter in the dough. Emulsifiers contain a fatty acid, palmitic or stearic acid, which are bound to one or more poly functional molecules with carboxylic, hydroxyl, and/or amino groups e.g glycerol, lactic acid, sorbic acid or tartaric acid. Sometimes the carboxylic group is converted to its sodium or calcium salt.

Emulsifiers are added as 0.5 % flour weight. Commonly used surfactants include: calcium stearoyl- 2-lactylate, lactylic stearate, sodium stearyl fumarate. Milk to be used in bread-making must be heated to high temperatures before being dried; otherwise, for reasons not yet known, the dough becomes sticky. Milk is added to make the bread more nutritious, to help improve the crust colour, presumably by sugar caramelization and because of its buffering value. Because of the rising cost of milk, skim milk and blends made from various components including whey, buttermilk solids, sodium or potassium caseinate, soy flour and/or corn flour are used. The milk substitutes are added in the ratio of 1-2 parts per 100 parts of flour.

About 2 % sodium chloride (salt) is usually added to bread. It serves the following purposes: it improves taste; it stabilizes yeast fermentation; has a toughening effect on gluten; helps retard proteolytic activity, which may be related to its effect on gluten; it participates in the lipid binding of dough. Because of the retarding effect on fermentation, salt is preferably added towards the end of the mixing. For this reason flake-salt which has enhanced solubility is used and is added towards the end of the mixing. Fat-coated salt may also be used; the salt becomes available only at the latter stages of dough or at the early stages of baking.

Water is needed to form gluten, to permit swelling of the starch, and to provide a medium for the various reactions that take place in dough formation. Water with high sulphide content is undesirable because gluten is softened by the sulphydryl groups. Sufficient amylolytic enzymes must be present during bread-making to breakdown the starch in flour into fermentable sugars. Since most flours are deficient in amylase, flour is supplemented during the milling of the wheat with malted barley or wheat to provide this enzyme. Fungal or bacterial amylase preparations may be added during dough mixing. Bacterial amylase from *Bacillus subtilis* is particularly useful because it is heat stable and partly survives the baking process.

Proteolytic enzymes from *Aspergillus oryzae* are used in dough making, particularly in flours with excessively high protein contents. Ordinarily however, proteases have the effect of reducing the mixing time of the dough. Mold inhibitors (Antimycotics): The spoilage of bread is caused mainly by the fungi Rhizopus, Mucor, *Aspergillus* and *Penicillium*. Spoilage by *Bacillus mesenteroides* (ropes) rarely occurs. The main anti-mycotic agent added to bread is calcium propionate. Others used to a much less extent are sodium diacetate, vinegar, monocalcium phosphate, and lactic acid. Bread is often enriched with various vitamins and minerals including thiamin, riboflavin, niacin and iron.

10.3 HEALTH BENEFITS

Cereal based fermented foods have their varied health benefits

- Fermentation enhanced the free radical scavenging ability of DPPH, and antioxidant activity increased after fermentation. During the fermentation process, the content of antioxidant polysaccharides, antioxidant peptides and phenolic compounds increased through microbial hydrolysis or biotransformation. The fermentation in many cases contributed to enhancing antioxidants' content and antioxidant capacity.
- Polyphenols, protein from fermented cereals, may be potentially used as functional food ingredients to prevent obesity and hyperlipidemia.
- Polyphones found in fermented products are beneficial to microbial metabolism and growth, and can inhibit the production of inflammatory cytokines.
- Fermented brown rice and rice bran with *Aspergillus oryzae* is an effective chemo preventive agent against inflammation related carcinogenesis that acts by inhibiting inflammatory cell infiltration into inflammatory lesions
- Fermented cereals have better anti inflammatory effects and can improve gastrointestinal immunity. These all help to improve the body's immune function.

10.4 FERMENTED FOOD FROM PULSES

Pulses are important crops that have a balanced nutritional composition and are among the most important sources of cheap and readily available starch, carbohydrate, protein, dietary fiber, minerals, and vitamins in food. Pulses also contain a number of bioactive compounds including phytates, oligosaccharides, enzyme inhibitors, and phenolic compounds. For human consumption, pulses are not eaten in its raw state, but after ensuing food processing, including boiling, cooking, puffing, grinding, germination (sprouting), and fermentation to increase their sensorial quality, appeal, esthetic value, and use. The most important pulses intended for human consumption include black gram, chickpea, dry broad bean, dry cowpea, field pea, mung bean, green gram, kidney bean, lentil, pigeon pea etc.

Pulses have been processed in developing countries for centuries using traditional processing techniques of grinding, fermentation, steeping, germination, dehulling, etc. and prior to consumption for further use. However fermentation remains largely important for pulse processing and gaining increased attention because of its improved functionalities, increase nutritional composition, and production of bioactive compounds.

Fermentation is defined as a processing technique used to convert substrates into new products through the action of microorganisms. Fermentation is also used in a broader sense for the intentional use of microorganisms to obtain useful products for humans on an industrial scale. Such industrial products may include biomass, enzymes, primary and secondary metabolites, recombinant, and biotransformation products. The biochemical changes that occur throughout the food fermentation process lead to the modification of the substrate (starch or sugar) and production of other compounds (such as acids and alcohols). Fermentation improves the texture, appearance, colour, flavour, shelf life, and also protein digestibility of pulses. It further decreases the presence of “antinutritional factors” including phytate, lectins, oligosaccharides, and protease inhibitors.

10.4.1 Microbial and biochemical changes during pulse fermentation

The micro organisms of fermented pulse based foods are largely dependent on temperature, pH, water activity, type of substrate, and salt levels. The three major types of microorganisms used during fermentation of pulses are bacteria of the genus *Bacillus*, *lactic acid bacteria* (LABs) and yeasts. In majority of these pulse based fermented foods, the fermentation process is spontaneous (natural), and thus a mixture of microorganisms may act sequentially. This may thus cause changing and non consistent products and possible production of pathogenic microorganisms and toxins. But, LABs are dominant, normally fastidious and grow willingly in most food substrates reducing the pH rapidly to a point where other competing organisms are no longer able to grow. Several industrial fermentations have also applied LABs for the production of functional foods and the production of enzymes/metabolites.

Fermentation of pulses as with other food crops is associated with reduction of pH; changes in carbohydrates (starch, fibers, saccharides, sugars), proteins (amino acids), and lipids; “antinutritional” factors; and enzymatic degradation of different compounds. It also leads to the improvement of texture, taste, and aroma of the final product. Aside from various modifications, fermentation of pulses is also associated with the formation of compounds as a result of microbial actions on endogenous compounds. Such compounds include alcohols, ketones, organic acids, and aldehydes that further contribute to the distinct aroma associated with fermented pulse based foods.

Pulse Based Fermented Foods from Different Countries

Product	Country of Origin	Substrates	Fermentation Type	Main Microorganisms Involved
Dawadawa	West and Central Africa	Locust bean and local pulses	Solid-state fermentation	*Bacillus subtilis, B. pumilus, B. licheniformis, Bacillus* spp.
Dhokla	India	Chickpeas, green gram, rice (2,2,1)	Liquid-state fermentation	*Lactobacillus fermentum, Leuconostoc mesenteroides, Streptococcus faecalis*
Doenjang	Korea	Black soybeans, local pulses	Liquid-state fermentation	*Leuconostoc mesenteroides, Enterococcus faecium, Tetragenococcus halophilus, Bacillus subtilis, Mucor plumbeus*
Cheonggukjang	Korea	Black soybeans, local pulses	Solid-state fermentation	*Bacillus subtilis, B. amyloliquefaciens, Rhizopus oligosporus*
Natto	Japan	Soybeans, local pulses	Solid-state fermentation	*Bacillus natto*
Tempeh	Indonesia, New Guinea, Surinam	Soybeans, chickpeas, groundnut, local pulses	Mold fermentation	*Rhizopus oligosporus, Aspergillus oryzae*
Ugba	Nigeria	Locust bean and local pulses	Solid-state fermentation	*Bacillus* ssp., *Staphylococcus, Micrococcus*
Wari	India, Pakistan	Black gram or bengal gram	Liquid-state fermentation	*Saccharomyces cereviseae, Candida krusei, Lactobacillus* ssp., *Leuconostoc mesenteroides, Lactobacillus fermentum*
Product	Country of Origin	Substrates	Fermentation Type	Main Microorganisms Involved
Dosa	India	Black gram and rice (1,1)	Liquid-state fermentation	*Leuconostoc mesenteroides, Lactobacillus delbrueckii, Lactobacillus fermentum, Streptococcus faecalis, Bacillus* spp., yeasts

Idli	India, Sri Lanka	Black gram and rice (1,2)	Liquid-state fermentation	*Leuconostoc mesenteroides, Lactobacillus delbrueckii, Lactobacillus fermentum, Lactobacillus lactis, Pediococcus cerevisiae, Streptococcus lactis, Streptococcus faecalis,* yeasts
Khaman	India	Chickpeas	Liquid-state fermentation	*Leuconostoc mesenteroides, Lactobacillus fermentum, Lactobacillus lactis, Pediococcus acidilactici, Bacillus* spp.

Source: Frias et. al., Fermented Pulses in Nutrition and Health Promotion. Institute of Food Science, Technology and Nutrition.

10.5 HEALTH BENEFITS OF FERMENTED PULSE PRODUCTS:

Fermentation has potential to improve the nutritional quality of pulses, providing protein, starch, fiber, and other health promoting compounds with physiological benefits contributing to the reduction of several risk factors associated with diabetes, cardiovascular diseases, colon cancer, stress, and aging. Moreover, fermented products derived from pulses can be considered as probiotic carriers and of benefit to gastrointestinal health.

- Fermented pulse products contain useful probiotic microorganisms that can improve gut health and related diseases.
- Fermented pulses provide a good source of proteins, peptides, and amino acids, which make them candidates to promote weight loss by sensation of fullness. They can modulate biological processes that counteract obesity.
- Among traditional pulses, mung beans have been recommended as a potential antidiabetic food for diabetic patients, and fermented foods also help to reduce the prevalence of diabetes in Asian populations. Fermented mung bean products have been recommended to manage diabetes due to their low GI, high fiber content, and phenolic compounds, which improve oxidative stress-induced hyperglycemia.
- Some fermented-legume products may contribute to lowering the risk of cardiovascular diseases due to their blood pressure lowering effects.

10.6 SUMMARY:

Cereals are essential sources of carbohydrates, proteins, minerals, fibers, and vitamins. Despite their drawbacks as deficiency in certain amino acids, lower protein content, presence of antinutrient compounds compared to products of animal origin or dairy foods, the fermented types of cereals are nutritionally superior to their native counterparts. Fermentation enhanced the free radical scavenging ability of DPPH, and antioxidant activity increased after fermentation. During the fermentation process, the content of antioxidant polysaccharides, antioxidant peptides and phenolic compounds increased through microbial hydrolysis or biotransformation. The fermentation in many cases contributed to enhancing antioxidants' content and antioxidant capacity.

Fermentation of pulses as with other food crops is associated with reduction of pH; changes in carbohydrates (starch, fibers, saccharides, and sugars), proteins (amino acids), and lipids; "anti nutritional" factors; and enzymatic degradation of different compounds.

Pulses are important crops that have a balanced nutritional composition and are among the most important sources of cheap and readily available starch, carbohydrate, protein, dietary fiber, minerals, and vitamins in food. Pulses also contain a number of bioactive compounds including phytates, oligosaccharides, enzyme inhibitors, and phenolic compounds. For human consumption, pulses are not eaten in its raw state, but after ensuing food processing, including boiling, cooking, puffing, grinding, germination (sprouting), and fermentation to increase their sensorial quality, appeal, esthetic value, and use.

10.7 TECHNICAL TERMS:

Phytates, phenolic compounds, anti oxidants, anti nutritional factors.

10.8 SELF ASSESSMENT QUESTIONS:

1) Discuss in detail about Significance of fermentation in cereal based foods
2) Write an account on microbial and biochemical changes during fermentation
3) Add a note on fermented pulse products
4) Explain about health benefits of fermented cereal products

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Dr. P. Kiranmayi

LESSON-11

VEGETABLES AND MILK PRODUCTS

11.0 OBJECTIVES:

After going through this lesson students will understand

- Changes in the fermented vegetables
- Health benefits of fermented vegetables
- Fermented milk products and their health benefits

STRUCTURE:

11. 1 INTRODUCTION

Fermentation is perhaps one of the oldest preservation methods practiced by human beings. The process of fermentation is the anaerobic catabolism of carbohydrates by microorganisms] and fermented foods are defined the foods that are made under controlled, desired microbial growth and enzymatic conversions of their major and minor components.

A fermented milk product from India, called Dahi, was mentioned in about 6000 to 4000 B.C. Fermented milk products such as sour milk, yogurt, and cheese, evolved throughout the Middle East, Europe, and India. In the hot climate of these areas, the summer temperatures can reach as high as 40 °C, milk turns sour within a short time of milking, and these conditions have possibly helped the sour milk to be processed into a viscous fermented milk product, similar to yogurt-like or concentrated yogurts. While it was evident very early that sour milks and yogurt-like products had enhanced shelf lives, compared with raw milk, these products evolved and gained special importance and popularity due to other properties such as improved nutritional value.

The fermentation of fermented vegetables is the result of microorganism metabolism based on the substrate of the raw materials and the added seasoning. Various complex biochemical reactions occur during the fermentation of fermented vegetables, involving microbial and nutritional composition changes. Multiple microbial organisms interact within the complex microbial microenvironment of fermented vegetables. Lactic acid bacteria and *Bacillus* bacteria are two kinds of essential microorganisms with significant functions.

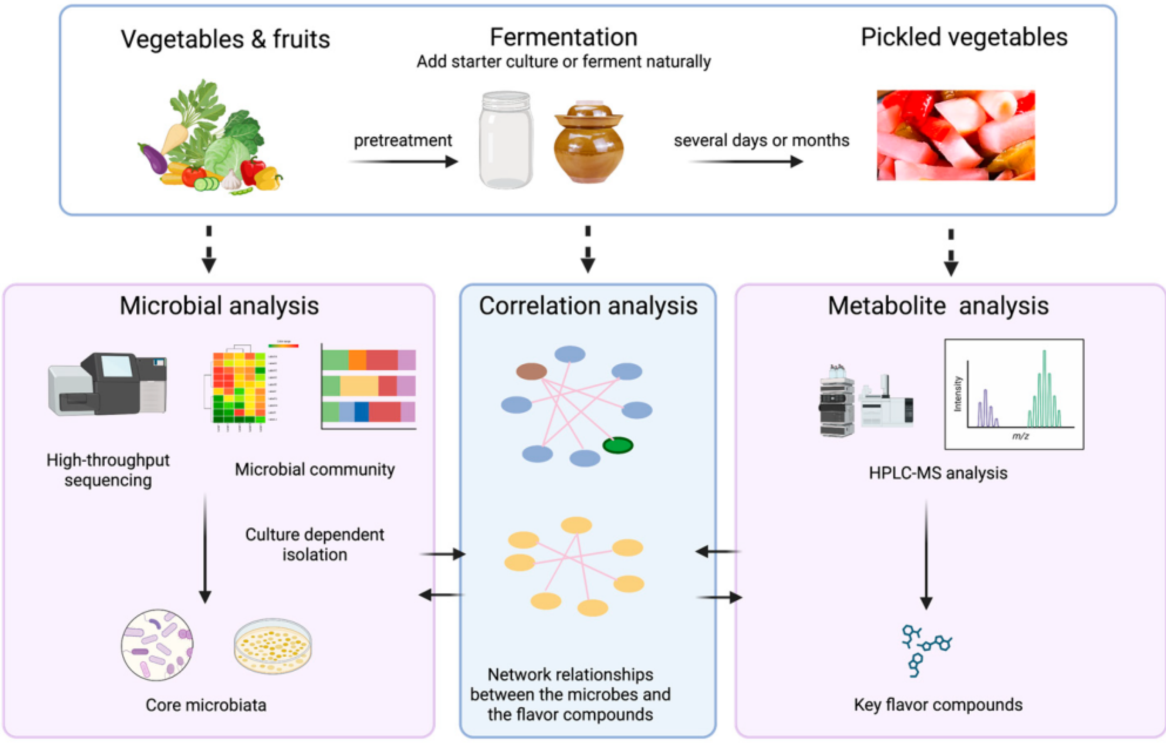
During the traditional fermentation process for fermented vegetables, their core microbial community is closely related to the ingredients, the place of the ingredient origin, the climate, the formula, the fermentation container, and the maker, which further affects the flavor of fermented vegetables. The flavour is a critical indicator for determining the quality of fermented vegetables; therefore, by analyzing the correlation of the core microbiota that contributes to the fermented vegetables with excellent quality and flavour, and maintaining or improving the portion of these “good” microbes in the meantime, unfavorable microorganisms that deteriorate fermented vegetables can be controlled by appropriately manipulating the environmental parameters and other influence factors on purpose; implementing this within the industrial production of fermented vegetables with anticipated qualities.

11.2 FERMENTED VEGETABLE PRODUCTS

The major fermented vegetable foods include sauerkraut from cabbage and pickles from cucumber, carrots, mixed vegetables, green tomatoes and olives. Gram negative bacteria are commonly found on vegetables in large numbers while lactic acid bacteria are less in numbers.

Fermentation basically involved the repression of gram negative bacteria by salting and stimulation of the growth of lactic acid bacteria by anaerobiosis and low water activity. Heterolactic *Leuconostoc mesentoroides* and *lactobacillus brevis* as well as homolactic *lactobacillus plantarum* and *Lactobacillus plantarum* are the naturally present lactic acid bacteria in cabbage. Temperature and salt concentration control the activity of the type lactic acidbacteria in the primary and secondary stages of fermentation. As a salt concentration of 2.25% and low temperatures (~7.5^{0}C), heterolactics predominate yielding sauerkraut of superior flavour and colour. Higher temperatures favour the more acid resistant homolactis.

Cucumber and olive pickles are made by fermentation oat higher sat concentrations. In the range of 5-8%, and the fermentation is mainly brought about by the homolactic *Lactobacillus Plantarum*



Steps in Pickled Vegetables Production

Source Created with BioRender.com
(**https://www.biorender.com**, accessed on 17 July 2023).

Acid Fermented Vegetables

Product name	Country	Major ingredients	Microorganisms
Sauerkraut	Germany	Cabbage, salt	*Leuconostoc mesenteroides, Lactobacillus brevis, Lactobacillus plantarum*
Kimchi	Korea	Korean cabbage, radish, various vegetables, salt	*L. mesenteroides, Lb. brevis, Lb. plantarum*
Dhamuoi	Vietnam	Cabbage, various vegetables	*L. mesenteroides, Lb. plantarum*
Dakguadong	Thailand	Mustard leaf, salt	*Lb. plantarum*
Burong mustasa	Philippines	Mustard	*Lb. brevis, Pediococcus cerevisiae*

Source: Ratan Das, Himanshu Pandey, Bappi Das, andSusmita Sarkar (2016) Fermentation and its Application in Vegetable Preservation: A ReviewIntl. J. Food. Ferment. Technol. 6(2): 207-217.

11.2.1 The Changes in the Fermented Vegetables

In terms of the nutritional value of fermented vegetables, they will initially lose water and vitamin C during the pickling procedure. The water loss is because of the relatively high salinity of the fermented vegetables. Salt penetrates the raw material through pores formed on the surface in response to the change in external pressure, and this could be regarded as the primary and significant step in fermentation. The salt transport follows the law of fluid mechanics based on the diffusion of a concentration gradient. During this process, the water activity within the fermented vegetables changed. For the rigid or smooth surface skin of some vegetables lacking pores, salt diffusion is retarded, which might result in a more extended fermentation period that may require several months to obtain the pickles' anticipated flavours. The loss of ascorbic acid is because of the blanching procedure in hot water.

Other nutrient compositions also varied. The content of soluble protein decreased, but the content of polypeptides and free amino acids increased due to the effect of the protease secreted by certain protease producing bacteria; the content of the umami, sweet, and bitter amino acids changes during the whole fermentation process, and the sweet amino acids (Thr, Ser, Gly, Ala, and Pro) would dominant as the fermentation continues]; in the period in between, the metabolic activity of strains such as *Lactobacillus* reduces the amount of anti nutrient substances such as those that promote protein cross linking and those that inhibit digestive enzymes; the presence of certain microorganisms can also promote the metabolic process in the human body, accelerate the decomposition of the toxins, and have the function of regulating and stabilizing the intestinal microenvironment. Consequently, the digestibility and bioavailability of the plant proteins in fermented vegetables are improved after consumption.

However, there are exceptions, such as fermented bamboo, whose soluble protein content would increase during fermentation (an increase from 3.1% - 7.8%) due to the proteolytic metabolic activities of the microorganisms, which make fermented bamboo a good source of digestible proteins. For fat content, certain vegetables, such as broccoli, cucumber, and pepper, which are commonly used as pickling ingredients, may exhibit an increase in lipid content during pickling, which is also related to the enzymatic activities of fermenting organisms. In contrast, the lipid content in bamboo stalks decreases. Fermentation alters the dietary fiber content of fermented vegetables by causing pectin disintegration in the cell wall and depolymerization under non enzymatic action; consequently, the texture of fermented vegetables will change.

11.2.2 Production of Other Nutritious Substances

The fermentation of fermented vegetables produces a variety of substances that are beneficial to the human body; fermentation significantly improves the nutritional value of leafy fermented foods. Different types of fermented vegetables produce different types of active substances. The nutritional content in the leaves of *Amaranthus* sp. was improved after fermenting compared with the original content. *Cruciferae* vegetables had the most significant variation in glucosinolates, polyphenols, and carotenoids. Most pickles have perfect antioxidant capacity due to the increase in the content of total phenols and flavonoids during fermentation. Phenolic substances can inhibit xanthine oxidase by affecting the enzyme’s secondary structure and hydrophobic groups, thus controlling uric acid content in the human body.

Fermented vegetables such as kimchi produce various short chain fatty acids, which would alter the structure of the host’s intestinal flora after intake. Fermented cucumbers produce GABA through the action of glutamate decarboxylase and arginine deiminase. In sauerkraut, glucosinolate breaks down into ascorbic acid and isothiocyanate, and in fermented olives, ascorbic acid and indole-3-carbinol were detected after marinating. Fermented garlic produces more riboflavin and R-tocopherol than unfermented garlic. Fermented vegetables can also increase ions’ bioavailability due to the formation of Fe^{3+}.

The stability of these active substances will change during the storage of fermented vegetables. The GABA produced by fermented cucumbers remains stable for over six months of storage, while its total phenols’ stability depends on storage conditions. At the same time, the content of the ascorbic acid and isothiocyanate produced by sauerkraut, as well as the ascorbic acid and indole-3-carbinol produced by fermented olives, would decrease during storage. Therefore, to achieve the optimal probiotic effect of fermented vegetables, the best eating time for fermented vegetables is also a factor to be considered.

11.2.3 Factors Affecting the Nutrient Changes in Fermented Vegetables

Changes in the nutritional components of fermented vegetables are influenced by various factors, including vegetable varieties, vegetable qualities, cultivation conditions, the addition of seasonings, pickling methods, and fermentation conditions. Different flavours are imparted to fermented vegetables by different raw materials. For instance, the pigment, antioxidant properties, gluconapin, gluconasturiin, and total isothiocyanates would be distinct when different leaf mustard varieties were chosen when producing Guizhou sauerkraut. Producing fermented vegetables using cabbage containing glucobrassicin could enhance the therapeutic effects of fermented vegetables on chronic diseases. The phenolic acid content of traditional fermented bell peppers is more significant when sweet peppers are harvested using conventional cultivation methods. On the contrary, most flavonoids and carotenoids are found in organic samples. The glutamic acid content of vegetables fermented with the addition of wheat bran increased significantly, and the levels of certain flavour compounds or components, such as free amino acids, α-linolenate, thiamine, and riboflavin, were increased. In addition, the level of sulfide compounds decreases, and the level of flavoring compounds rises, resulting in a significant reduction in the spicy flavour of fermented vegetables.

The fermentation conditions indirectly affect the nutrient changes in fermented vegetables. They would affect the nutritional composition of sauerkraut by interfering with the hydrolysis of volatile glucosinolates during fermentation. The effect of the containers used in fermented vegetable production on their quality has also garnered considerable attention. The output of fermented vegetables in plastic containers has the fastest fermentation rate, and the concentrations of lactic acid and succinic acid were relatively high. In contrast, pickles in porcelain vessels contain more volatile compounds and do not deteriorate quickly.

11.2.4 Health Benefits of Fermented Vegetables

The nutritional components generated during the pickling process and the probiotics in fermented vegetables are generally responsible for the health benefits of fermented vegetables. The health benefits of fermented vegetables include antibacterial effects, improvements in constipation, anticancer properties, the treatment of chronic diseases, the alleviation of irritable bowel syndrome, and immunity enhancement.

11.3 DEVELOPMENT OF VALUE ADDED PRODUCTS FROM VEGETABLES

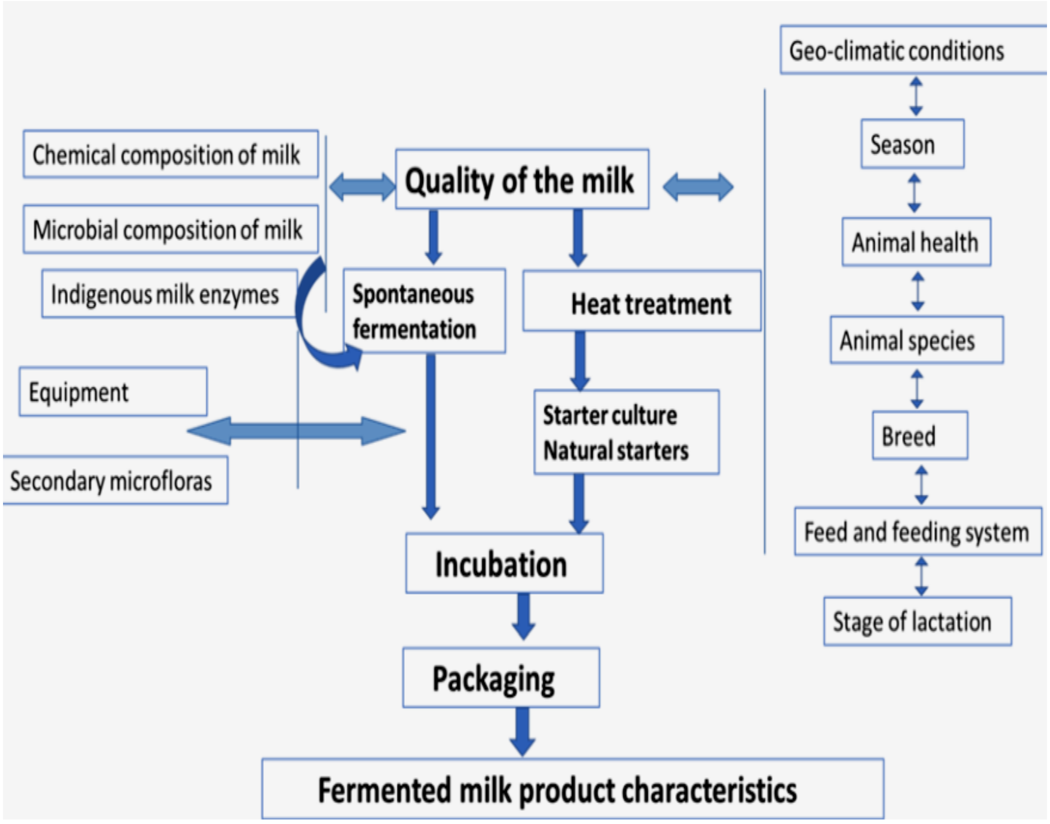
Gundruk, sinki and khalpi are the fermented vegetable products of Sikkim. It is observed that LAB comprising *Lactobacilli*, *pediococci* and *leuconostocs* were the predominant microorganisms present in viable numbers. Sauerkraut is the traditional fermented cabbage product. It is produced by the fermentation of cut and salted cabbage by naturally occurring lactic acid bacteria. outer green and dirty leaves are removed and cores of the heads are partly removed; cabbage is shredded to 0.7-2.2 mm wide strips; shredded cabbage is salted with 0.7 to 2.5 % sodium and cores of the heads are partly removed; cabbage is shredded to 0.7-2.2 millimeter wide strips; shredded cabbage is salted with 0.7 to 2.5 %sodium chloride; salted, shredded cabbage is placed into fermentation containers; fermentation takes place within a few hours and continues between seven days and several weeks. Many Organism play a vital role in sauerkraut fermentation. It is initiated by *Leuconostoc mesenteroides*, a hetero fermentative LAB, converting fermentable sugars of cabbage, which are primarily glucose and fructose in to lactic acid, mannitol, acetic acid, ethanol and carbon dioxide. *L. mesenteroides* typically dominates the early fermentation since it is present in larger numbers. Formation of lactic and acetic acids rapidly reduce the pH in the weakly buffered brine and inhibits the growth of undesirable microorganisms and activities of their enzymes, which may cause the cabbage to spoil and soften. Sauerkraut fermentation is complex and involves many chemical, physical and microbiological factors that influence quality of the product. Lactic acid bacteria as important in the sauerkraut fermentation: *Streptococcus faecalis, Leuconostoc mesenteroides, Lactobacillus brevis,* Pediococcus pentocaceus and *Lactobacillus plantarum*. Changes in lactic acid bacterial flora throughout spontaneous fermentation of Chinese sauerkraut showed that fermentation process was initiated by *Leuconostoc mesenteroides* sub sp. mesenteroides, followed by *Enterobacter faecalis, Lactobacillus lactis, L. zeae* and finally succeeded by *L. plantarum and L. case*

11.4 TYPES OF FERMENTED MILKS

Milks of various mammal species are used for the manufacture of fermented milk products differ in chemical composition, including significant differences in parameters such as total solids, lactose, fat, protein, and mineral content.

There is great variation in the chemical composition of milk from the same species and many factors may affect the gross composition of milk; the factors most significantly affecting the processing of milk products are geo-climatic conditions, animal health, breed, feed, season, and the stage of lactation.

Cow’s milk is the basis for most dairy fermented products around the world. Milk from other mammals, including sheep, goat, camel, mare, buffalo, and yak may have been historically more important and remain so in certain regions.



Factors Affecting the Uniqueness of Fermented Milk Products

Source: https://www.mdpi.com/2311-5637/8/12/679

11.4.1 Fermented Dairy Products

Milk is a highly unstable food as it is a very good medium for the growth of many microorganisms. Fermentation of milk is primarily mean at preservation by conversion into more stable, nutritious and desirable products such as cheese, yoghurt, buttermilk and butter. Milk from cows, sheep, goats and other mammals may be used directly for fermentation or after preliminary treatment such as pasteurization, ultra filtration or lactose hydrolysis. The fermentation may be initiated spontaneously by native microflora or by addition of specific starter cultures or material from previous fermentation. The fermented milk may undergo further processing to yield a more concentrated product or may be blended with other ingredients such as salts, fruits, herbs, spices, sugars and natural colourants to change flavour, appearance and texture of such products

The microorganisms used in the industrial scale of fermentation of cow's milk include mainly lactic acid producing bacteria such as the mesophilic *Lactococcus* and *Leuconostoc* species with optimum growth temperature in the range of 20-30^{0}C and thermophilic *Lactobacillus* and *Streptococcus* species used at temperature up to 45^{0}C. Other bacteria such as *Cotynebacterium*, *Penicillium cameberti* and *Penicillium candidum* are also used.

The nutrients in cow's milk include lactose (~4.5%), protein (~3.5%),fat (~4%) and citrate which are utilized by the micro organisms. lactose is converted in to lactic acid homolactically or into lactic acid, carbon dioxide and ethanol heterolactically. The milk proteins are hydrolyzed to individual amino acids by the proteolytic enzymes of the starter culture. The amino acids contribute to the flavour either by themselves or by yielding aldehydes, amines, alcholos and various sulphur compounds via decarboxylation, transamination, deamination and desulphurization reactions.

For example, *Propionibacterium* produces proline containing peptides and prolin is considered to be an important contributor to the sweetness in Swill type of cheese. Another protein metabolic product is ammonia, it is responsible for the flavour of camembert cheese. *Penicillium* sp. produces hydrogen sulphide, dimethy sulphide and methane thiol from methionine.

The flavour of youghrt is due to acetaldehyde derived from the degradadtion of threonine catalyzed by threonine aldolase of *Lactobacillus bulgaricus*. Citrate is metabolized by *Lactobacillus bulgaricus, Lactococcus lacctis, Lactococcus cremoris* and others to an intermediate product α- acetolactate, which is decarboxylated to diaacetyl, the characteristic flavour compound of butter, buttermilk and cottage cheese. In additon, carbon dioxide is also an end product of citrate metabolism contributing to the formation of 'eyes' in certain types of cheese such as gouda cheese. The milk fat is not utilized directly by starter cultures of lactic acid bacteria as they are weakly lipolytic. But other organisms constituting the second flora hydrolyze milk fat to liberate free fatty acids.

Fermented Dairy Products

S.No.	Name	Type of Milk	Micro-organisms involved
1	Curd	Buffalo's or cow's milk	*L. lactis* subsp. *lactis* *L. delbrueckii* subsp. *bulgaricus* *L. plantarum* *Streptococcus lactis* *S. thermophilus* *S. cremoris*
2.	Yoghurt	Cow's milk	*L. acidophilus* *S. thermophilus* *L. bulgaricus*
3.	Cultured butter milk	Buffalo's or cow's milk	*S. lactis subsp. diacetylactis* *S. cremoris*
4.	Lassi	Buffalo's or cow's milk	*L. bulgaricus*
5.	Acdiophilus milk	Cows milk	*L. acidophilus*
6	Bulgarian butter milk	Cow's milk	*L. delbueckii* subsp. *bulgaricus*
7.	Shrikhand	Buffalo's or cow's milk	*S. thermophilus* *L. bulgaricus*
8.	Kumiss	Mare's, camel's or ass's milk	*L. acidophilus* *L. bulgaricus* *Saccharomyces* *Micrococci*
9.	Kefir	Sheep's, cow's, goat's or mixed milk	*S. lactis* *Leuconostoc sp.* *Saccharomyces* *Kefir, Torula kefir, Micrococci*
10.	Leben	Goats, sheep's milk	*S. lactis* *S. thermophilus* *L. bulgaricus* Lactose fermenting yeast
11.	Cheese	Cow's, Buffalo's, goat's milk, sheep milk	*L. lactis* subsp. *lactis, L. lactis* subs *lactis* subsp. *diacetylactis, S. therm* *bueckii* subsp. *bulgaricus* *Prioponibacterium shermanii,* *Penicillium roqueforti* etc.

11.4.2 Health Benefits

11.4.2.1 Improvement of Lactose Intolerance

The inability of adults to digest lactose, or milk sugar, is prevalent worldwide. Consumption of lactose by those lacking adequate levels of lactase produced in the small intestine can result in symptoms of diarrhea, bloating, abdominal pain and flatulence. Milk with cells of *L. acidophilus* aids digestion of lactose by such persons.

11.4.2.2 Protection against Gastrointestinal Infection

Gastrointestinal infections including diarrhoea result from a change in the gut microflora caused by an invading pathogen. It is suggested that viable lactic acid bacteria interfere with the colonization and subsequent prolif eration of food borne pathogens, thus preventing the manifestation of infection. *L. bulgaricus, L. aci dophilus, S. thermophilus and B. bifidum* have been involved in this effect.

11.4.2.3 Anti carcinogenic activity

Fermented milk products can protect against certain types of cancers. Consumption of yoghurt, gouda cheese, butter milk protect against breast cancer. Animal studies have shown that lactic acid bacteria exert anti carcinogenic effect either by prevention of cancer initiation or by suppression of initiated cancer.

11.4.2.4 Antihypertensive Activity

Two antihypertensive peptides have also been purified from sour milk fermented with *L. helveticus* and *Saccharomyces cere visiae.* These two peptides inhibit angiotensin converting enzyme that converts angiotensinogen I to angiotensinogen II, which is a potent vasoconstrictor.

11.5 SUMMARY:

Various complex biochemical reactions occur during the fermentation of fermented vegetables, involving microbial and nutritional composition changes. Multiple microbial organisms interact within the complex microbial microenvironment of fermented vegetables. Lactic acid bacteria and *Bacillus* bacteria are two kinds of essential microorganisms with significant functions. During the traditional fermentation process for fermented vegetables, their core microbial community is closely related to the ingredients, the place of the ingredient origin, the climate, the formula, the fermentation container, and the maker, which further affects the flavor of fermented vegetables. Milk is a highly unstable food as it is a very good medium for the growth of many microorganisms. Fermentation of milk is primarily mean at preservation by conversion into more stable, nutritious and desirable products such as cheese, yoghurt, buttermilk and butter. Milk from cows, sheep, goats and other mammals may be used directly for fermentation or after preliminary treatment such as pasteurization, ultra filtration or lactose hydrolysis. The fermentation may be initiated spontaneously by native microflora or by addition of specific starter cultures or material from previous fermentation.

11.6 TECHNICAL TERMS:

Lactobacillus bulgaricus, Gundruk, sinki and khalpi, cheese.

11.7 SELF ASSESSMENT QUESTIONS:

1) Discuss about changes occur in vegetables during fermentation process
2) Write an essay on fermented dairy products and their health benefits
3) Add a note on development of value added products from vegetables

11.8 REFERENCE BOOKS:

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Dr. P. Kiranmayi

LESSON-12

BEVERAGES, MEAT PRODUCTS

12.0 OBJECTIVES:

After going through this lesson students will understand

- Alcoholic beverage and non alcoholic beverages.
- Various types of Non dairy fermented beverages.
- Fermented meat products.

STRUCTURE:

12.1 INTRODUCTION

In general, a drink is a liquid substance which is mainly made for human consumption and it is generally called a beverage (various liquids for drinking, usually excluding water).

Beverages can be divided into several categories:

- Hard or alcoholic beverages
- Soft or non-alcoholic beverages
- Fruit or vegetable juices and
- Hot drinks such as coffee and hot chocolate.

Beside to fulfilling a basic biological need, beverages form part of human culture as well. Beverages are prepared by fermentation of carbohydrates sources using specific strains of microorganism (yeast in beer production). An alcoholic beverage is a drink that contains ethanol. A non alcoholic drink is one that contains little or no alcohol. Such includes low alcohol wine and non-alcoholic beer if they contain less than 0.5% alcohol by volume.

12.2 ALCOHOLIC BEVERAGES

An alcoholic beverage is a drink that contains ethanol and legally consumed in most countries around the world. Alcoholic beverages are a source of food energy. Each gm of alcohol provides 7.1 kcal and each ml provides 5.6 kcal. In general, alcohol (ethanol, ethyl alcohol) is usually prepared from sugar, starch and other carbohydrates by fermentation with yeast and sometimes, synthetically from ethylene or acetylene. It is colorless, clear, very mobile, flammable liquid, a pleasant odor and miscible with water and with many organic liquids. Ethanol has a slightly sweet taste and a characteristic aroma. Alcoholic beverages are commonly called by one of several names based on the source of the sugar. The most common sources are fruit, grain and sugar but some other sources of fermentable sugars like vegetables may be used as well.

12.2.1 Beer

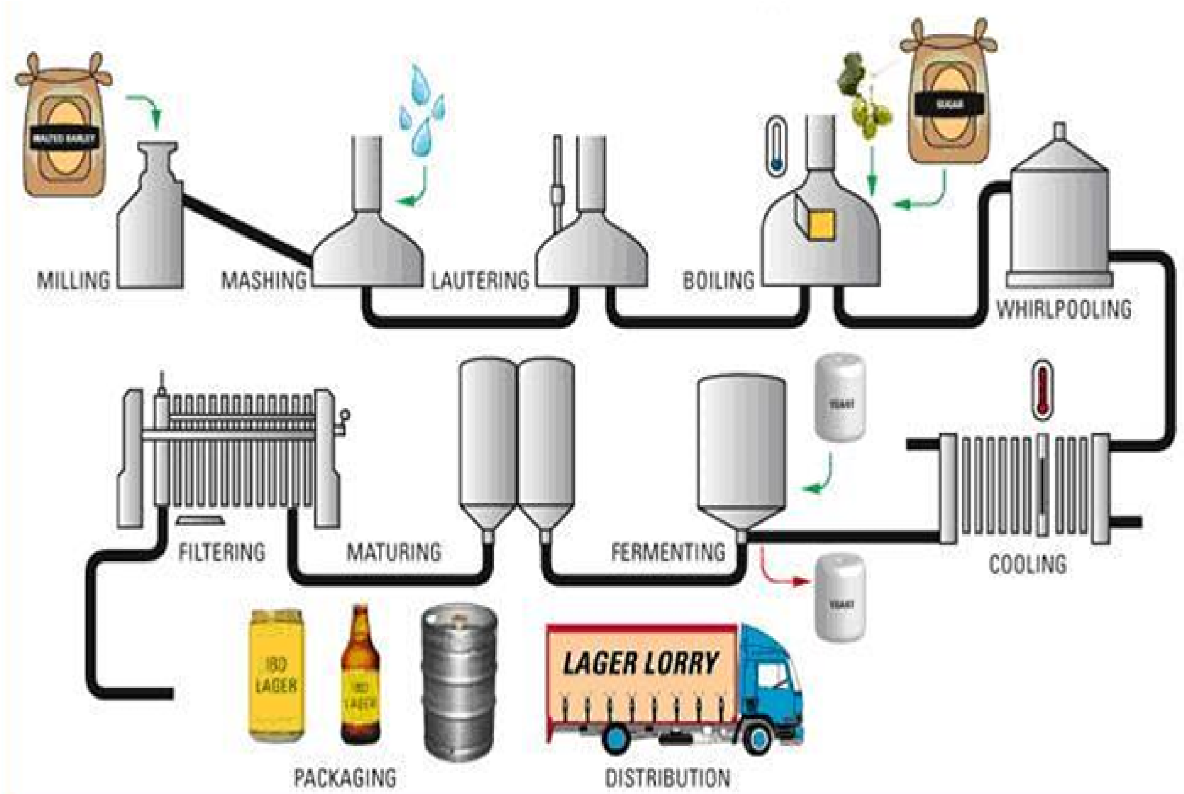
It is the world's most commonly consumed alcoholic beverage and is the third-most popular drink overall, after water and tea and it is believed by some to be the oldest fermented beverage. In general, beer is an alcoholic beverage (usually around 4% - 6% alcohol by volume, however, it may vary between 0.5% and 20%) produced by the saccharification of starch and fermentation of the sugar. The carbohydrate source (starch) and saccharification enzymes are often derived from malted cereal grains. Generally, malted barley and malted wheat and most beer are also flavoured with hops (which add bitterness and act as a natural preservative). Some other flavourings such as herbs or fruit may sometimes be incorporated.

The process of making beer is called brewing, which includes breaking the starch in the grains into sugary liquid, so called wort and fermenting the sugars in the wort into alcohol and CO_2 by microbes (yeasts).

In this fermentation process, two main species are involved:

- *Saccharomyces cerevisiae* (top-fermenting), as it forms foam on top of the wort and used to produce lagers.
- *Saccharomyces uvarum* (bottom-fermenting) used to produce ale

The temperature used for top-fermenting (15-24ºC) induces the production of a lot of esters and flavor products that give beer a fruity taste. Hops are added during boiling as a source of bitterness, flavour and aroma. Though, hops may be added at more than one point throughout the boil. The lengthier the hops are boiled, the more bitterness they add, but the less hop flavor and aroma leftovers in the beer. Brewer's yeasts are very rich in essential minerals and B vitamins, with the exception of vitamin B12. Nowadays, beer brewing is performed by added pure cultures of the desired yeast species to the wort. After the fermentation is over, the beer is cleared of the yeasts by precipitation or with the use of clearing additives and it is packaged either into casks for kegs, aluminum cans or bottles for other kinds of beer.



Production of Beer

Source:

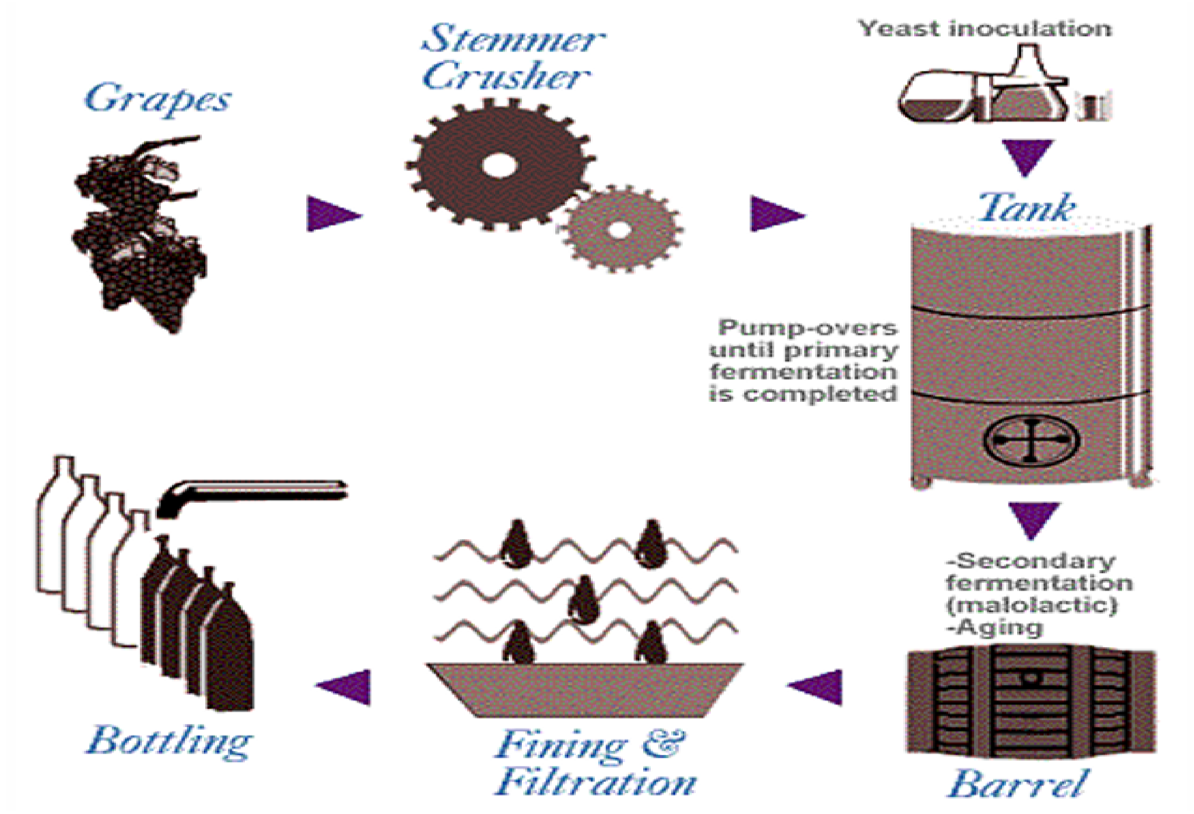
ttp://chem409.wikispaces.com/file/view/industrial_brewing_flow_chart.jpg/104567945/

12.2.2 Wine

It is an alcoholic beverage can be made from fermented grapes or other fruits. Several varieties of grapes and strains of yeasts produce different styles of wine. Wines made from produce besides grapes are usually named after the product from which they are produced (pomegranate wine, rice wine, elderberry wine and apple wine) and are generically called fruit wine. In general, the term wine can also refer to starch fermented or fortified beverages having higher alcohol content, like barley wine, huangjiu or sake etc.

12.2.2.1 Steps of wine making process

- Crusher: The grapes are first cleaned of leaves and stems and the fruit is crushed into must that is ready for fermentation. Therefore, grapes are conveyed to a destemmer/crusher where grape leaves and stems are removed and grapes are crushed.
- Fermentation: Most red grapes go to the fermenter for primary fermentation while most white grapes are pressed prior to fermentation. Yeast (*Saccharomyces cerevisiae*) is added to start the fermentation. However, there are hundreds of commercially available yeast strains for wine fermentation and it is significant to keep the temperature in the fermentation vessel lower than 40ºC to keep the yeasts alive. Furthermore, to improve yeast growth, some extra nutrients, like diammonium phosphate, are may be added in this step.
- Press: After completion of fermentation, the red wines go to press to separate the wine from the grape skins.
- Tank: Most wines are settled in large stainless steel or upright oak tanks.
- Barrel: After settling, red wines and fuller-bodied white wines are put into small oak barrels for aging.
- Filter: After barrel aging and earlier to bottling, certain wines are filtered to help stabilize and clarify them.
- Bottle: Finished wines are bottled.
- Aging: Wines may be aged further in a bottle if desired. Wine also has proven following health benefits:
  - Red wine is rich in flavonoids and it may protect your heart by reducing LDL (bad) cholesterol, increasing HDL (good cholesterol) and reducing blood clotting.
  - White wine can help to improve lung function.



Process of Wine Making

Source: http://www.davidstuff.com/winemaking.gif

12.3 NON ALCOHOLIC BEVERAGES

Non alcoholic beverages are also known as a virgin drink. It is defined in the United States as a beverage that contains less than 0.5% alcohol by volume. In general, non alcoholic versions of some alcoholic beverages like non alcoholic beer (near beer) and cocktails (mock tails), are most widely accessible where alcoholic beverages are retailed. Sodas, juices and sparkling cider comprise little or no alcohol.

12.3.1 Kombucha

Kombucha is a raw, fermented, probiotic and naturally carbonated drink It is made by inoculating a sweetened tea with fermenting SCOBY (Symbiotic Culture of Bacteria and Yeast). After steeping tea in boiling water and allowing it to cool, a SCOBY is added to tea and allowed to ferment in a warm room (25-28°C) for 1-2 weeks. The fermented drink is sour from the acetic acid produced by the culture and can be drunk still or carbonated.

Health benefits of kombucha are:

- Detoxification: It is rich in many of the enzymes and bacterial acids to detox the system, thus reducing pancreatic load and easing the burden on the liver.
- Joint Care: Kombucha contains glucosamines (a strong preventive and treatment all types of arthritis).

- Aids Digestion and Gut Health: Due to its naturally fermented with a living colony of bacteria and yeast.
- Immune Boosting: It is strangely antioxidant rich and boosting immune system and energy levels.

12.3.2 Kefir Kefir

It is a fermented milk drink that originated in the Caucasus region and known for its nutritional and probiotic benefits. It was traditionally fermented in leather sacks placed by a door and people were expected to kick or shake the sack as they entered the household. Kefir is produced by microbial activity of kefir grains (starter culture) consisting of lactic acid bacteria and lactose fermenting yeast. Such, microbes produce organic acids like lactic acid, acetic acid and alcohol, which give kefir its characteristic properties and flavor. In addition, the production of organic acid (acidic nature) gives an antimicrobial property to the mixture that inhibits the growth of most undesirable (spoilage causing) microbes.

The health benefits of kefir include:

- Reduction of lactose intolerance symptoms
- Stimulation of the immune system
- Lowering cholesterol
- Antimutagenic and anticarcinogenic properties

12.4 NON DAIRY FERMENTED BEVERAGES

It is another important class of fermented beverages is those made from cereals, which are popular in tropical regions and in Africa. As with many milk-based products, the natural microbial component is used to ferment grains including maize, millet, barley, oats, rye, wheat, rice or sorghum. The grains are usually heated, mashed and sometimes filtered.

12.4.1 Boza: Consumed in Bulgaria and Turkey, is generated through the fermentation of a variety of cereals including barley, oats, rye, millet, maize, wheat or rice, with the specific composition affecting the viscosity, fermentability and content of the final beverage. The cereal is boiled and filtered, a carbohydrate source is added, and the mixture can be left to ferment independently or with the use of back slop. Boza has yet to be commercialized and studies have revealed that the microbial population varies. The function of the yeast present, which is only sometimes detected, remains unknown. Of several combinations, it has been suggested that fermentation by *Saccharomyces cerevisiae*, *Leuconostoc mesenteroides* and *Lactobacillus confusus* produce the most palatable beverage.

12.4.2 Togwa: A sweet and sour, non alcoholic beverage, is one of the better studied African cereal beverages. Produced from the flour of maize, sorghum and finger millet and, sometimes, cassava root, the chosen substrates are boiled cooled and fermented for approximately 12hours to form a porridge, which is then diluted to drink.

12.4.3 Mahewu: is similar in that maize or sorghum meal is fermented with millet or sorghum malt, and is available commercially.

12.4.4 Bushera: Generally prepared from germinated or non germinated sorghum grains, and fermented for 1-6 days. These beverages are often used to wean children, and as a high energy diet supplement.

12.4.5 Koko sour water: is the fermented liquid wate rcreated in the production of the fermented porridge, koko. This contains a high portion of LAB and is used by locals to treat stomach aches and as a refreshing beverage.

12.4.6 Kvass: A fermented rye bread beverage common in Russia, which has seen much commercial success. The beverage can have a sparkling, sweet or sour, rye bread flavour. Its alcohol content, though usually low, can vary, and has been suggested as a contributor to alcoholism.

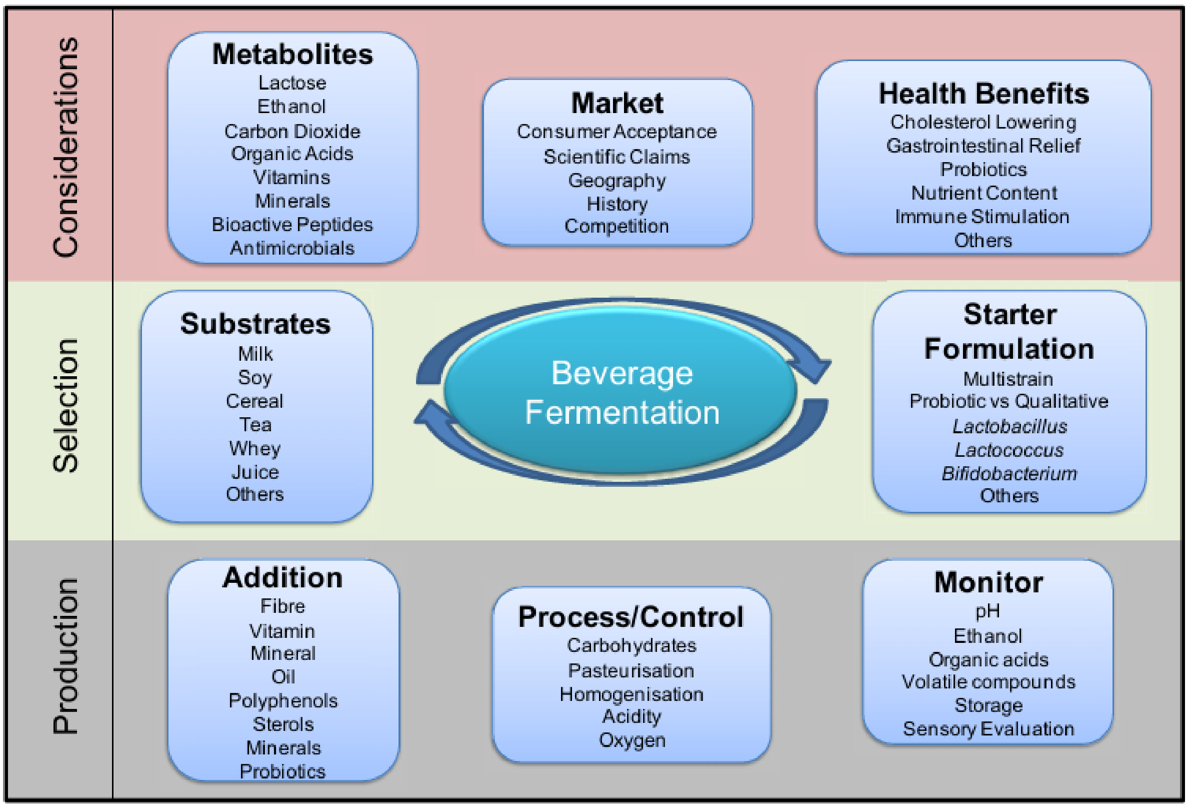
12.4.7 Amazake: A sweet fermented rice beverage that is the non alcoholic precursor to sake, produced in Japan. Steamed rice is mixed with rice-koji (*Aspergillus* mycelia and rice) and water, and is heated to 55-60^{0}C for 15-18 hours. Enzymes breakdown the rice and form glucose content of approximately 20%. Amazake is highly nutritious and is consumed for its purported health benefits.

12.4.8 Pozol: It is a common to south-eastern Mexico, has quite a different method of production, in that maize grains are heat treated in an acid solution, ground and shaped into dough balls. These are then wrapped in banana leaves and fermented for 2-7 days, after which they are re suspended in water and consumed as beverages. Pozol is composed of a variety of microorganisms including LAB, non-LAB, yeasts and other fungi.

Fermented Beverages Around the World

Product	Substrates	Region	Microflora
Amasi	Milk (cow, various)	Africa (Zimbabwe)	*Lactococcus* (*L. lactis*), *Lactobacillus, Leuconostoc, Enterococcus.* Uncharacterised fungal component
Aryan	Milk (cow, various)	Turkey	LAB: *Lactobacillus bulgaricus, Streptococcus thermophilus*
Garris	Milk (camel)	Africa (Sudan)	Bacteria: *Lactobacillus* (*Lb. paracasei, Lb. fermentum* and *Lb. plantarum*), *Lactococcus, Enterococcus, Leuconostoc.* Uncharacterised fungal component
Kefir	Milk (cow, various)	Eastern Europe (Caucasian region)	Bacteria: *Lactococcus, Lactobacillus, Leuconostoc, Acetobacter*; Yeast: *Naumovozyma, Kluyveromyces, Kazachstania*
Kivuguto	Milk (cow)	Africa (Rwanda)	LAB: *Leuconostoc* (*Leu. mesenteroides, Leu. pseudomesenteroides*) and *L. lactis.* Uncharacterised fungal component
Koumiss/Airag	Milk (horse)	Asia/Russia	LAB: *Lactobacillus*; Yeast: *Kluyveromyces, Saccharomyces* and *Kazachstania*
Kumis	Milk (cow)	South America (Columbia)	Bacteria: *Lb. cremoris, L. lactis, Enterococcus* (*E. faecalis, E. faecium*); Yeast: *Galactomyces geotrichum, Pichia kudriavzevii, Clavispora lusitaniae, Candida tropicalis*
Nyarmie	Milk (camel)	Africa (Ghana)	LAB: *Leu. mesenteroides, Lb. bulgaricus, Lb. helveticus, Lb. lactis, Lactococcus lactis*; Yeast: *Saccharomyces cerevisiae*
Rob	Milk (unspecified)	Africa (Sudan)	LAB: *Lb. fermentum, Lb. acidophilus, L. lactis, Streptococcus salivarius*; Yeast: *Saccharomyces cerevisiae, Candida kefyr*
Suusac	Milk (unspecified)	Africa (Kenya)	LAB: *Leu. mesenteroides, Lactobacillus* (*Lb. plantarum, Lb. cruvatus, Lb. salivarius, Lb. Raffinolactis*); Yeast: *Candida krusei, Geotrichum penicillatum, Rhodotorula mucilaginosa*
Shubat	Milk (camel)	China	Bacteria: *Lactobacillus* (*Lb. sakei, Lb. Helveticus, Lb. brevis*) *Enterococcus* (*E. faecium, E. faecalis*), *Leu. lactis and Weissella hellenica*; Yeast: *Kluyveromyces marxianus, Kazachstania unisporus,* and *Candida ethanolica*
Amazake	Rice	Japan	Fungi: *Aspergillus* spp
Boza	Various (barley, oats, rye, millet, maize, wheat or rice)	Balkans (Turkey, Bulgaria)	LAB: *Leuconostoc* (*Leu. paramesenteroides, Leu. sanfranciscensis, Leu. mesenteroides*), *Lactobacillus* (*Lb. plantarum, Lb. acidophilus, Lb. fermentum*); Yeast: *Saccharomyces* (*S. uvarum, S. cerevisiae*), *Pichia fermentans, Candida* spp.
Bushera	Sorghum, millet flour,	Africa (Uganda)	Bacteria: *Lactobacillus, Streptococcus, Enterococcus.* Uncharacterised fungal component
Koko Sour Water	Cereal (pearl millet)	Africa (Ghana)	Bacteria: *Weissella confusa, Lb. fermentum, Lb. salivarius, Pediococcus* spp. Uncharacterised fungal component
Kvass	Rye bread, rye and barley malt/flour,	Russia	LAB: *Lb. casei, Leu. mesenteroides*; Yeast: *Saccharomyces cerevisiae*
Mahewu	Maize, sorghum/millet	Africa (Zimbabwe)	Unknown
Pozol	Maize	Mexico (Southeast)	Bacteria: *L. lactis, Streptococcus suis, Lactobacillus* (*Lb. plantarum, Lb. casei, Lb. alimentarium, Lb. delbruekii*), *Bifidobacterium, Enterococcus.* Uncharacterised fungal component
Togwa	Maize flour, finger millet malt,	Africa (Tanzania)	LAB: *Lactobacillus* spp.; Yeast: *Saccharomyces cerevisiea, Candida* spp.
Hardaliye	Grapes/mustard seeds/cherry leaf	Turkey	LAB: *Lactobacillus* spp. Uncharacterised fungal component
Kombucha	Tea	China, Worldwide	Bacteria: *Gluconacetobacter (G. xylinus), Acetobacter, Lactobacillus*; Yeast: *Zygosaccharomyces, Candida, Hanseniaspora, Torulaspora, Pichia, Dekkera, Saccharomyces*
Water Kefir	Water/sucrose	Mexico, Worldwide	Bacteria: *Lactobacillus* (*Lb. casei, Lb. hilgardii, Lb. brevis, Lb. plantarum*), *L. lactis, Leu. mesenteroides, Zymomonas*; Yeast: *Dekkera* (*D. anomola, D. bruxellensis*), *Hanseniaspora* (*H. valbyensis, H. vineae*) *Saccharomyces cerevisiae, Lachancea fermentati, Zygosaccharomyces* (*Z. lentus, Z. florentina*)

Source: Alan J. et. al. (2014) Fermented beverages with health-promoting potential: Past and future perspectives Marsh,trends in food science &Technology 38:113-124



Considerations in fermented beverage production and development

Source: Alan J. et. al. (2014) Fermented beverages with health-promoting potential: Past and future perspectives Marsh, trends in food science &Technology 38:113-124.

12.5 FERMENTED MEAT PRODUCTS

The sterile tissues of animals on slaughtering become contaminated by spoilage and patghogenic Gram-negative bacteria such as *E.coli*., *Salmonella species*, *Pseudomans species* and *Clostridium perfringens* and also some Gram positive species. As a measure of preservation meat, its water activity is reduced by salting or curing by addition of nitrite or drying. Acid fermentation of meat is carried out to enhance the stability, texture, colour and flavour of the product by choosing appropriate starter cultures. In the manufacture of fermented meat products, starter cultures mainly of *lactobacillus plantarum* and micrococcus are used. The majority of fermented products may be classified in to dry sausages with a moisture content of 25% to 45% and semi dry sausages with a moisture content of ~50%. Meat curing compounds and starter culture are mixed and stuffed in casings at low temperatures of about -5^{0}C and incubated at a temperature between 20 and 40^{0}C for fermentation. The fermented product is dried at 10-20^{0}C. Acid formation during fermentation also quickens the process of drying. The dry fermented meat sausages include pepperoni and salami while bologna and summer sausages are semi dry fermented meat sausages. Fermented poultry sausages include dry as well as semi dry turkey sausages.

12.6 SUMMARY:

Beverages form part of human culture as well. Beverages are prepared by fermentation of carbohydrates sources using specific strains of microorganism (yeast in beer production). An alcoholic beverage is a drink that contains ethanol. An alcoholic beverage is a drink that contains ethanol and legally consumed in most countries around the world. Alcoholic beverages are a source of food energy. In general, non alcoholic versions of some alcoholic beverages like non alcoholic beer (near beer) and cocktails (mock tails), are most widely accessible where alcoholic beverages are retailed. Non dairy fermented beverages are another important class of fermented beverages is those made from cereals, which are popular in tropical regions and in africa. As with many milk-based products, the natural microbial component is used to ferment grains including maize, millet, barley, oats, rye, wheat, rice or sorghum. the grains are usually heated, mashed and sometimes filtered. In the manufacture of fermented meat products, starter cultures mainly of *lactobacillus plantarum* and micrococcus are used.

12.7 TECHNICAL TERMS:

Kombucha, Amazake, Pozol, sausages.

12.8 SELF ASSESSMENT QUESTIONS:

1) Describe in detail about alcoholic beverages
2) Write an account on non dairy fermented beverages
3) Discuss in detail about fermented meat products

12.9 REFERENCE BOOKS:

1) Food microbiology, fermented beverages-e pathshala.
2) Alan J. et. al. (2014) Fermented beverages with health-promoting potential: Past and future perspectives Marsh, trends in Food Science &Technology 38:113-124.

Dr. P. Kiranmayi

LESSON-13

PROCESSING AND PRESERVATION BY NOVEL METHODS: PULSED X-RAYS, MICROWAVE, RADIO FREQUENCY, MINIMAL PROCESSING, EDIBLE COATINGS AND FILMS, MEMBRANE PROCESSING, HURDLE TECHNOLOGY

13.0 OBJECTIVES:

After going through this lesson students will understand

- To enhance food safety and shelf-life using novel preservation methods like pulsed X-rays, microwave, and radio frequency.
- To improve food quality through minimal processing techniques, preserving nutrients and flavours.
- To optimize food processing using membrane technology for better separation and filtration.

STRUCTURE:

13.1. INTRODUCTION

Food processing and preservation are essential for ensuring food safety, extending shelf life and maintaining nutritional quality. Traditional methods like drying, freezing and thermal pasteurization have been widely used but they often lead to nutrient loss, texture degradation and changes in sensory attributes.

As food safety regulations become more stringent the adoption of novel processing and preservation methods is expected to grow. These techniques not only help manufacturers comply with hygiene and safety standards but also offer competitive advantages by improving product quality and extending market reach. With continuous advancements in food science and technology the future of food preservation will be driven by innovative, sustainable and efficient solutions that meet the evolving needs of consumers while ensuring a safer and more reliable global food supply.

13.2. NOVEL METHODS OF FOOD PROCESSING AND PRESERVATION

To overcome these limitations novel food processing technologies have been developed focusing on minimal processing, higher efficiency and better preservation of natural food quality. These methods are

- Irradiation
- High-Pressure Processing (HPP)
- Ultrasound Processing
- High-Intensity Light Processing
- Pulsed Electric Field (PEF)
- Ohmic Heating
- Pulsed X-rays
- Microwave and Radio Frequency Processing
- Minimal Processing
- Edible Coatings and Films
- Membrane Processing

13.2.1. IRRADIATION

Food irradiation is a modern preservation technique that uses ionizing radiation to eliminate harmful microorganisms, insects and spoilage agents from food products. This method extends shelf life, enhances food safety and reduces post-harvest losses. Unlike thermal processing, irradiation does not significantly alter the taste, texture or nutritional value of food making it a preferred alternative for preserving perishable items. The process is widely accepted by food safety organizations like the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the Food and Drug Administration (FDA).

Principle:

Irradiation works by exposing food to controlled doses of ionizing radiation which damages the DNA of microorganisms preventing their growth and reproduction. The process does not make food radioactive as the energy levels used are insufficient to induce radioactivity. The three primary types of ionizing radiation used in food irradiation are:

- **Gamma rays** (Cobalt-60, Cesium-137)
- **X-rays** (generated from high-energy electron beams)
- **Electron beams (E-beam)**

Each type has unique penetration abilities and is chosen based on the food product being processed.

Fig. 13.2.1: Food Irradiation

Process of Food Irradiation

The irradiation process involves several steps:

Pre-Irradiation Handling – Food is cleaned, sorted and packed in radiation-compatible materials. Exposure to Ionizing Radiation – The food is placed in a chamber where it is exposed to a specific radiation dose. Radiation Absorption – Microbial cells absorb radiation energy, leading to DNA damage and microbial death. Post-Irradiation Storage and Distribution – Irradiated food is tested for safety and stored under proper conditions before reaching consumers.

Techniques Used in Food Irradiation

Several irradiation techniques are used depending on the type of food and desired preservation effect:

Low-Dose Irradiation (Up to 1 kGy): Used for inhibiting sprouting in tubers and delaying ripening in fruits.

Medium-Dose Irradiation (1–10 kGy): Effective for eliminating insects, parasites and non spore forming bacteria in meat, poultry and seafood.

High-Dose Irradiation (Above 10 kGy): Used for sterilizing food products like spices and hospital diets to make them pathogen free. Used in irradiation of fruits and vegetables, meat and poultry, dairy products

Advantages:

Enhances food safety by reducing pathogenic bacteria, extends shelf life without the need for preservatives and preserves nutritional value better than thermal processing. This prevents post harvest losses benefiting global food supply chains.

13.2.2. High Pressure Processing (Hpp) in Food Preservation

High Pressure Processing (HPP) is an advanced non-thermal food preservation technique that uses extremely high pressure (100–600 MPa) to inactivate microorganisms and enzymes while preserving the food quality. Unlike traditional thermal methods, HPP maintains the freshness, flavor, color and nutritional content of food products. This technology is widely used in industries such as fruit juice, seafood, dairy, meat and ready-to-eat meals ensuring safety and extended shelf life without chemical preservatives.

Principle:

HPP works by subjecting food to hydrostatic pressure which is uniformly applied in all directions. This high pressure disrupts microbial cell membranes leading to inactivation, alters enzyme activity slowing down spoilage reactions and modifies protein structures which can improve texture in some foods. Since pressure is applied uniformly HPP-treated food retains its original shape and structure unlike thermal treatments that cause shrinkage or expansion.

High-Pressure Processing Equipment and Procedure:

The HPP process consists of several key steps:

1. Loading – Packaged food is placed inside a high-pressure chamber.
2. Water Immersion – The chamber is filled with water to create uniform pressure. Pressurization – High pressure (typically 300–600 MPa) is applied for a few seconds to minutes.
3. Holding Phase – Pressure is maintained to inactivate microbes and enzymes. Decompression and
4. Unloading – Pressure is released, and food is removed for storage or distribution. HPP equipment is designed to handle bulk processing while maintaining food integrity.

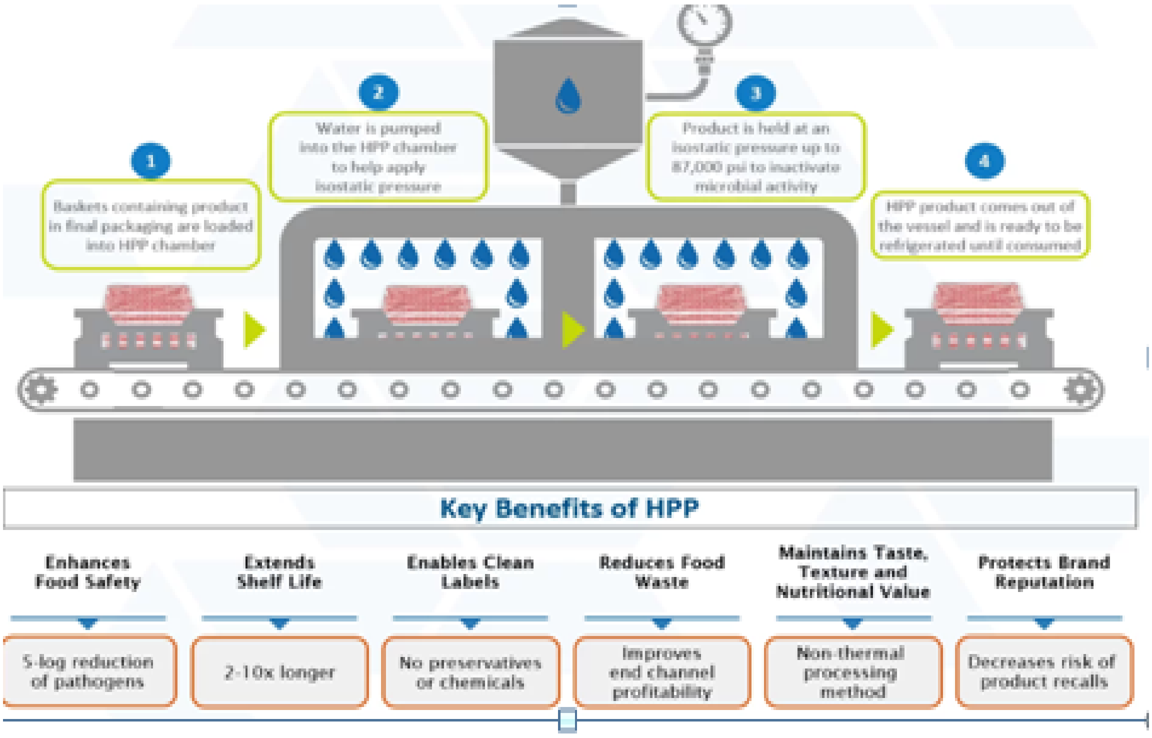


Fig. 13.2.2: High-Pressure Processing Equipment

Advantages of High-Pressure Processing:

- Non-Thermal Process – Preserves natural taste, color and nutrients.
- Extended Shelf Life – Reduces spoilage, minimizing food waste.
- No Chemical Preservatives – Supports clean-label food trends.
- Uniform Processing – Ensures consistent food safety and quality.
- Retains Fresh-Like Quality – Ideal for premium and organic food products.

13.2.3. ULTRASONIC PROCESSING

Ultrasonic processing is an emerging non thermal food preservation technique that uses high frequency sound waves (20 kHz to 100 MHz) to modify food properties, inactivate microorganisms and improve extraction and mixing processes. This method is particularly useful in liquid and semi-solid foods where it enhances homogenization, emulsification and microbial reduction while maintaining nutritional and sensory quality. Ultrasonic processing is widely applied in the food industry for juice processing, dairy treatment, meat tenderization and enzyme inactivation.

Principle:

Ultrasonic waves generate acoustic cavitation which involves the rapid formation, growth and collapse of micro-bubbles in liquids. This phenomenon creates localized high pressure and temperature disrupting microbial cells. Shear forces and turbulence aiding in mixing and extraction. It increases enzymatic activity modulation thereby enhancing food stability. By applying these effects ultrasound can effectively improve food texture, shelf life and overall quality.

Types of Ultrasounds Used in Food Processing:

Ultrasound applications in food processing are classified into two categories:

- **Low-Intensity Ultrasound (LIU) (≤1 W/cm²)**
  - o Used for quality assessment such as detecting food defects or monitoring processing changes. Common in meat tenderness evaluation and milk homogenization.
- **High-Intensity Ultrasound (HIU) (10–1000 W/cm²)**
  - o Used for microbial inactivation, emulsification and extraction. Applied in juice processing, dairy treatment and food preservation.

Fig. 13.2.3: Ultrasonic Processing

Microbial Inactivation by Ultrasound:

Ultrasonic processing inactivates bacteria, yeast and mould by disrupting their cell membranes. It is effective against *E. coli*, *Salmonella* and *Listeria* in liquid foods. Works well in combination with heat (thermosonication) or pressure (manosonication) for spore inactivation. Preserves probiotic cultures in fermented dairy when optimized. This microbial inactivation helps improve food safety while maintaining its fresh-like characteristics.

Examples:

- Juice and beverage processing, dairy products, seafood processing, edible oil and fat processing, baking and confectionery.

13.2.4. Pulse Electric Field:

Pulsed Electric Field (PEF) processing is a non-thermal food preservation technique that applies short pulses of high-intensity electric fields (20-80 kV/cm) to liquid foods. This process induces electroporation disrupting microbial cell membranes while preserving the foods flavour, colour and nutrients. With minimal heat generation PEF is an effective alternative to conventional pasteurization particularly for juices.

PEF treatment occurs at low temperatures (<50°C) for a very short duration (<1s) reducing energy loss. While it inactivates vegetative bacteria and yeasts it does not eliminate spores or fully deactivate enzymes requiring refrigeration post-processing. Additionally, PEF enhances juice extraction improving yield without compromising quality.

Advantages:

PEF is a gentle and waste free technology. It helps preserve the physical and sensory qualities of food. PEF can be used continuously the process is quick and uniform for electrically conductive foods. It requires a short treatment time and low energy.

Disadvantages:

PEF systems are expensive to install and maintain. It is most effective against vegetative cells but may require additional methods for full preservation. Solid foods with low water content do not work well with PEF. Voltage and pulse duration must be carefully controlled to avoid over-processing and ensure food safety.

13.2.5. High Intensity Light

Rapid and effective low thermal, low energy purification and sterilisation technique by use of very high power and short duration light pulses emitted by inert gas flash lamps.

Principle:

(ultra violet 180 to 400 nm, visible light-400 to 700nm, Infra-Red 700 to 1100 nm). Ultraviolet rays of short wave length and high energy were used and with total energy being equal power provided by pulses is greater than that provided by continuous.

Application of high Intensity light in food Processing and preservation

- High Intensity light treatment given to eggs surface decontamination.
- Continuous flow intensity light system for bacterial inactivation in fruit juices and milk.
- Decontamination of food powders using pulsed ultraviolet (UV) light.
- Pulsed light treatment for decontamination of chicken from food pathogens pulsed light treatment for freshly cut mushroom.

Advantages:

The Intensity of light that lasts for only a second is 20,000 times brighter than sunlight but there is no thermal effect, so quality and nutrient content are retained. The xenon-flash lamps used in pulsed light treatment are more eco-friendly than the mercury vapour lamps used in ultraviolet (UV) treatment.

Disadvantages:

Prolonged exposure to high intensity light can degrade vitamins and sensitive nutrients reducing the nutritional value of food. Light exposure can cause oxidation leading to undesirable colour changes and off-flavours especially in dairy products, oils and meats. High intensity light can accelerate fat oxidation in foods containing oils and fats leading to rancidity and spoilage.

13.2.6 OHMIC HEATING

Introduction:

Ohmic heating is a food processing technology that uses electrical resistance heating to heat food products. It involves passing an electric current through the food generating heat due to electrical resistance.

How it works: Ohmic heating involves passing an electric current through a food product. The electrical resistance of the food generates heat which is then distributed throughout the product.

Applications:

Food Processing: Pasteurization, sterilization, cooking and heating of food products.

Liquid Foods: Soups, sauces, juices and other liquid foods.

Solid Foods: Meat, poultry, seafood and other solid foods.

Pharmaceuticals: Sterilization and processing of pharmaceutical products.

Advantages:

Fast Heating: Ohmic heating heats food quickly and uniformly.

Energy Efficiency: Ohmic heating can be more energy-efficient than traditional heating methods.

Minimal Nutrient Loss: Ohmic heating helps preserve nutrients and flavours.

Reduced Processing Time: Ohmic heating can reduce processing times increasing productivity.

13.2.7 Pulsed X- Rays

Introduction:

Pulsed X-rays are a form of ionizing radiation used for sterilization, food irradiation and medical device sterilization. This technology involves generating high-energy X-rays in short bursts (pulses).

How it works: Pulsed X-rays involve exposing food to high-energy X-rays in short bursts (pulses). This ionizing radiation kills bacteria and other microorganisms.

Fig. 13.2.4: Pulsed X- Rays

Applications:

Food Irradiation: Sterilizes food products, extending shelf life.

Medical Device Sterilization: Sterilizes medical devices, ensuring safety.

Pharmaceutical Sterilization: Sterilizes pharmaceutical products.

Research and Development: Used in various research applications.

Advantages:

Effective Sterilization: Pulsed X-rays effectively kill bacteria and other microorganisms.

Minimal Heat Generation: Reduces damage to sensitive materials.

High Penetration: X-rays can penetrate dense materials.

Reliable and Consistent: Provides consistent and reliable sterilization results.

13.2.8. MICROWAVE HEATING

Microwave heating is a process that uses non-ionizing radiation to heat and cook food. Microwaves penetrate the food causing water molecules to vibrate and generate heat.

Pasteurization of milk:

- **Collection and Storage**: Collect raw milk and store at 4°C.
- **Standardization**: Adjust fat and quality levels.
- **Pasteurization and Homogenization**: Heat and homogenize milk to ensure safety and uniformity.
- **Packaging and Storage**: Pack milk in sterile containers and refrigerate.

- **Quality Testing and Distribution**: Test for quality and distribute while keeping it cold.

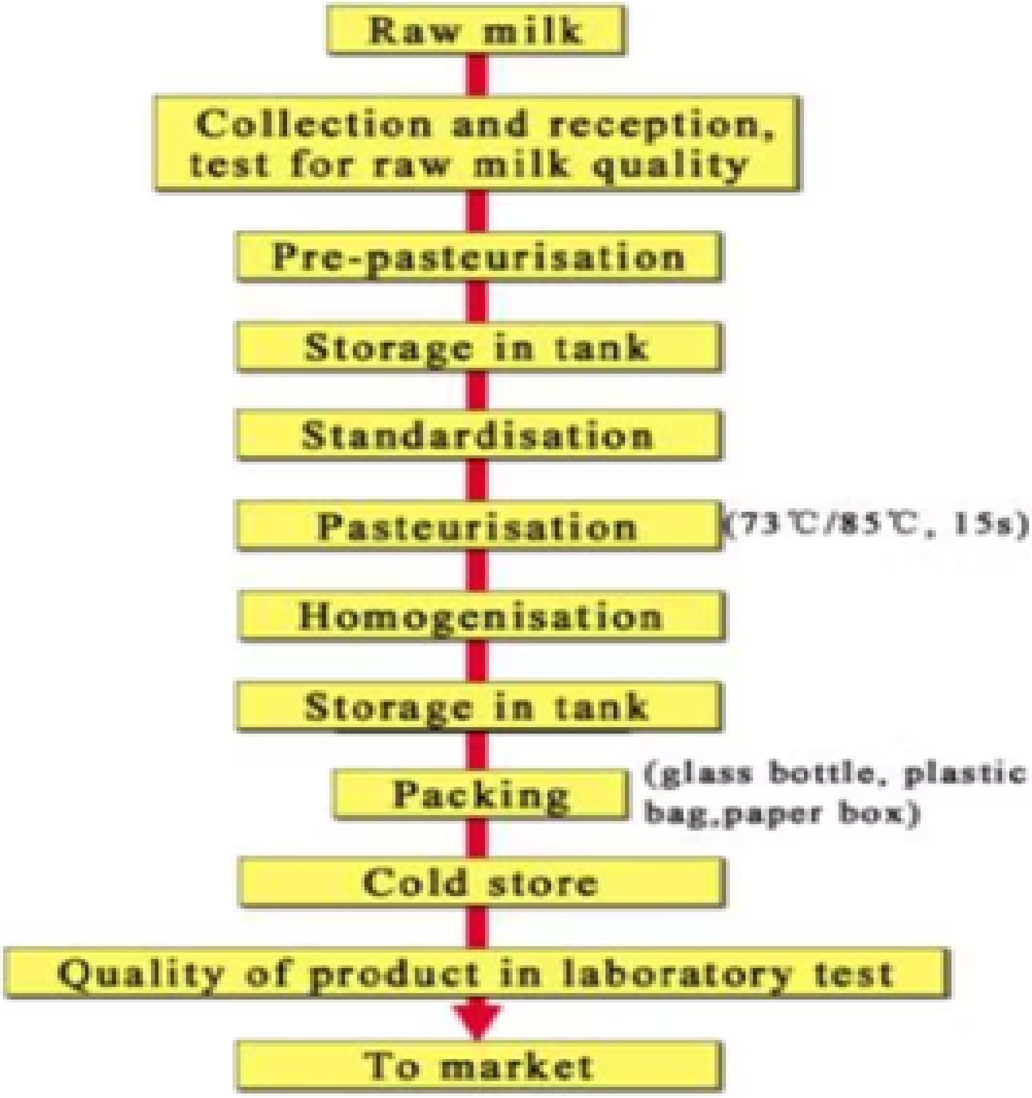


Fig. 13.2.5: Procedure for Pasteurization of milk

Vacuum Drying of Fruits and Vegetables:

Procedure of Vacuum Drying:

- **Preparation**: Select, clean and cut fruits or vegetables.
- **Osmotic Dehydration**: Soak in a concentrated sugar or salt solution to remove water.
- **Rinsing**: Wash off excess sugar or salt.
- **Vacuum Drying**: Dry under vacuum at 50–60°C while controlling pressure and time.
- **Packaging**: Pack dried products in airtight containers and store properly.

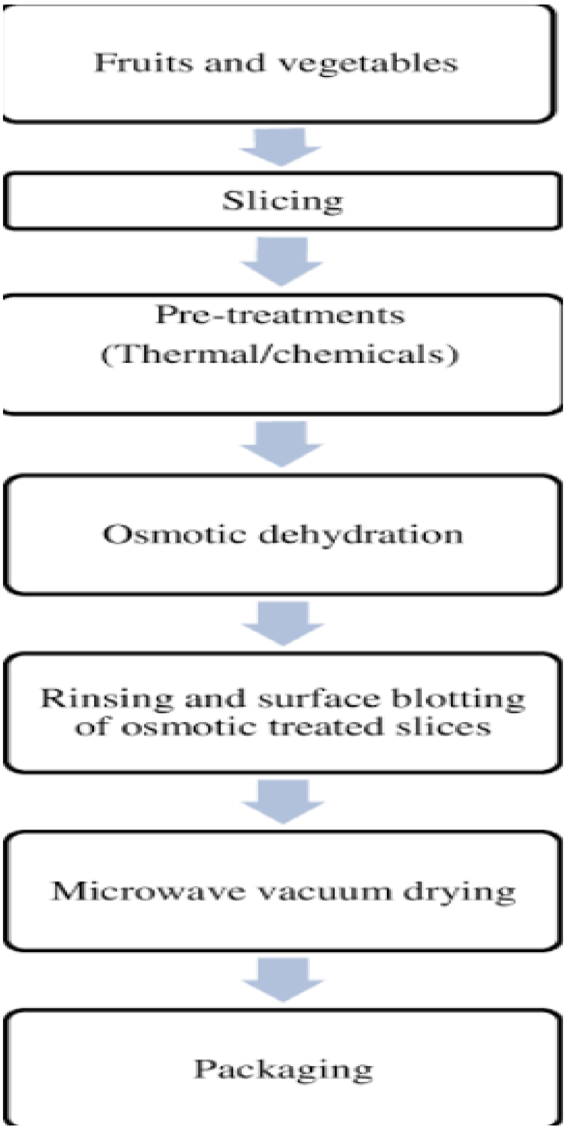


Fig. 13.2.6

Applications:

- Food Reheating: Quickly reheats cooked food.
- Cooking: Cooks a variety of foods including frozen meals and vegetables.
- Drying: Dries fruits, vegetables and herbs.
- Pasteurization: Pasteurizes food products extending shelf life.

Advantages:

- Fast Heating: Microwaves heat food quickly and efficiently.
- Energy Efficiency: Microwave heating can be more energy-efficient than traditional heating methods.
- Convenience: Microwave ovens are quick and easy to use.
- Minimal Nutrient Loss: Microwave heating helps preserve nutrients and flavours.

13.2.9. Radio Frequency:

Radio frequency (RF) is a promising thermal-processing technology for food applications because of its related rapid heating, larger penetration depth and lower consumption of energy. This chapter deals with the various applications of RF processing associated with food industries. Radio frequency (RF) heating is a commonly used food processing technology that has been applied for drying and baking as well as thawing of frozen foods. Its use in pasteurization as well as for sterilization and disinfection of foods is more limited. This column will review various RF heating applications in food processing as well as the basic principles of this technology.

Fig. 13.2.7: Radio Frequency Machine

Basic Science: RF (Radio Frequency) processing uses electromagnetic waves to heat food. These waves have frequencies between 3 kHz and 300 MHz with 13.56 MHz, 27.12 MHz and 40.68 MHz being allowed in the U.S. During RF processing food is exposed to an alternating electric field causing polar molecules like water to rotate and create heat through friction. This heating method is fast and heats food evenly unlike traditional heating methods. Additionally dissociative ions in food generate heat by moving back and forth in the electric field.

Equipment Design: RF heating equipment comes in two types: traditional oscillator systems and the newer Crystal Oscillator Source Matched Impedance Generator (COSMIG) systems. The traditional systems are cheaper and simpler while COSMIG systems offer precise control over frequency and power allowing for more accurate control over food processing such as moisture content. The most common RF system used is the parallel plate "through-field" system though other systems with rod or tube-shaped electrodes are used for specific food types.

Applications of Radio Frequency: RF drying is widely used in cookie, cracker, cereal and snack manufacturing to avoid surface cracking ensure even moisture distribution and maintain flavour and colour. It reduces drying times from 30 minutes in traditional baking to 8-10 minutes with RF resulting in faster more energy-efficient processing. RF baking also prevents mold and staling in bread and other techniques like infrared can be used for crust formation.

RF technology offers faster and more efficient solutions for food processing compared to traditional methods. For defrosting, it quickly heats large product blocks reducing bacteria growth, drip losses and product deterioration. In sterilization and pasteurization, RF provides uniform rapid heating preserving product quality while being more energy-efficient than steam or hot water methods. It's used in meat processing and for treating dry ingredients like flour and grains. Additionally, RF can be used for disinfestations offering a chemical-free alternative to fumigants and has been shown effective for treating fruits and nuts.

13.2.10. Minimal Processing in Food:

Minimal processing in food refers to techniques that preserve essential characteristics of food. These techniques include: Washing, Peeling, Cutting, Packaging, Cold temperature storage under film

Washing:

Wash hands and kitchen surfaces often. Wash hands with soap and water for 20 seconds before and after handling food. Clean utensils, cutting boards and countertops with hot, soapy water.

Rinse fruits and vegetables under running water.

Peeling:

Always use a chopping board when peeling. Peel fruits and vegetables by moving the peeler away from your body. For long foods like carrots, hold one end, peel from the middle outward and then switch ends and peel the rest.

Cutting:

- Chop: Cut food into small rough pieces.
- Slice: Cut food into thin flat pieces.
- Dice: Cut food into small even cubes
- Julienne: Cut food into thin matchstick-like strips.

Packaging:

Food packaging wraps protects food to keep it safe, fresh and good to eat. It protects food from damage, germs and changes caused by air, light and physical impact. Packaging is an important part of keeping food safe during storage and transport.

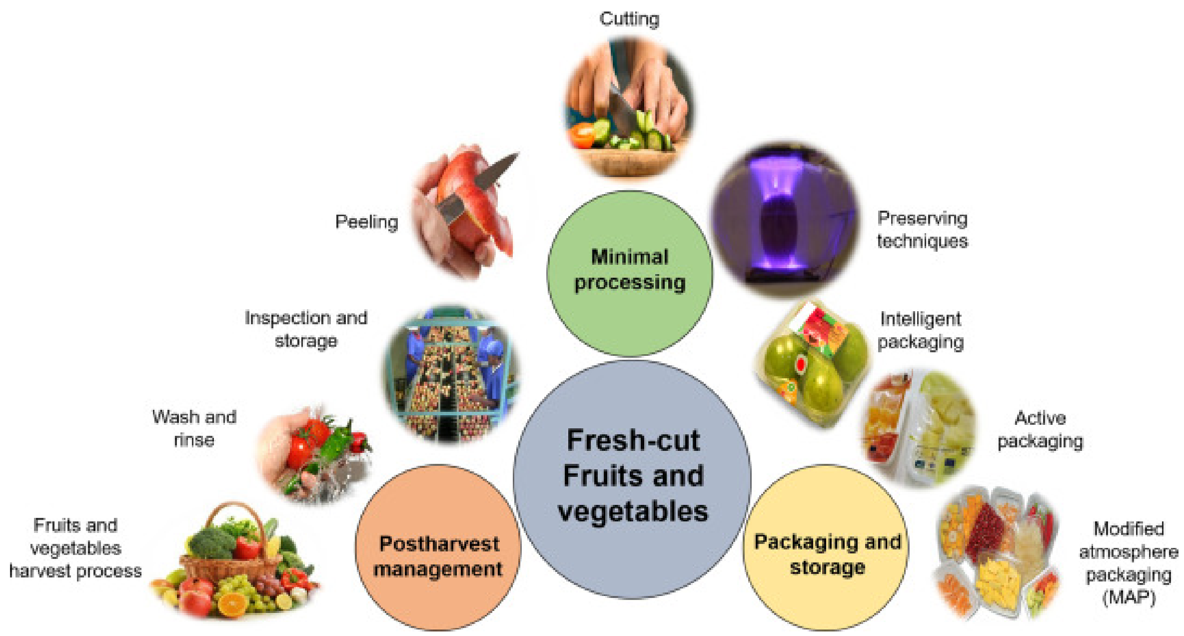


Fig. 13.2.8: Minimal Processing in Food

13.2.11. Edible Films and Coatings:

Food preservation faces challenges in extending shelf-life especially for perishable products like meat, fish and fruits. Modern techniques aim not only at preservation but also at using environmentally friendly processes without harming health. One approach is edible films and coatings which can replace traditional packaging materials that contribute to waste. These biodegradable alternatives are increasingly explored to reduce pollution.

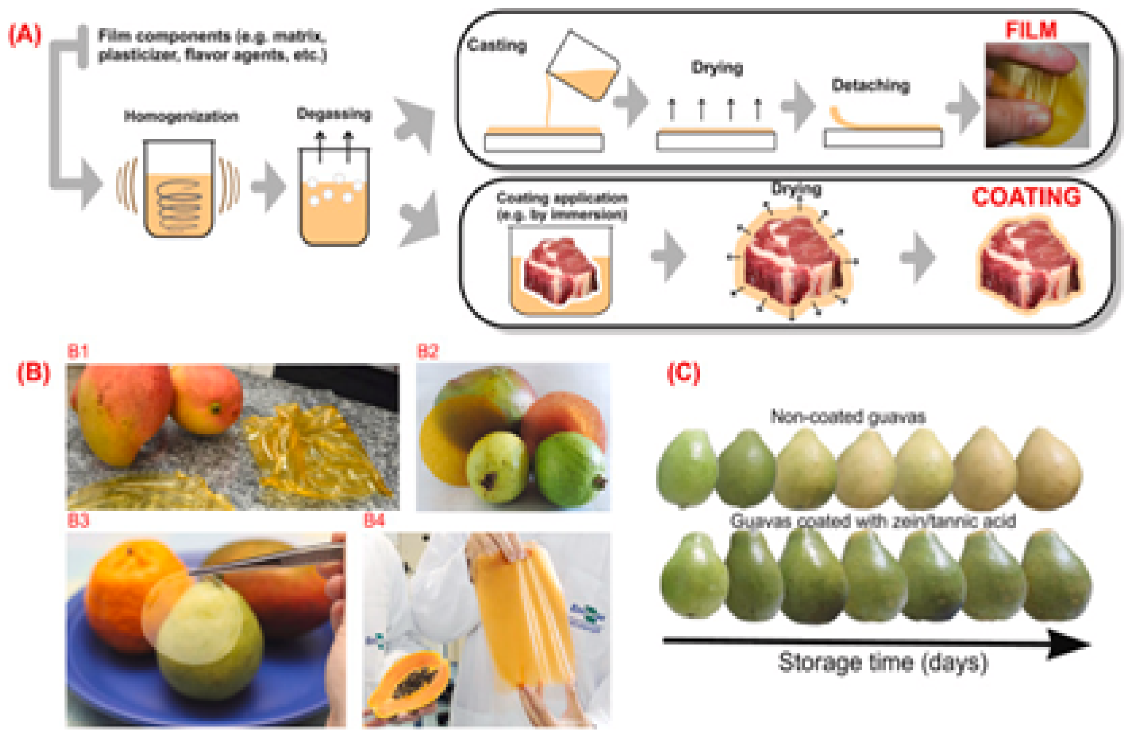


Fig. 13.2.9: Process of Edible Films and Coating

Classification of Edible Films and Coatings:

Edible films and coatings are classified by their main ingredients from:

Polysaccharide: Made from starch, pectin, cellulose, etc., these films are good for fruits and vegetables by reducing respiration though they have poor moisture barrier properties.

Protein: Modified animal and plant proteins like gelatin, soy and gluten create films with enhanced functional properties increasingly used in food packaging.

Lipid: Waxes and fats like beeswax and carnauba wax have been used for centuries to preserve food by preventing moisture loss and enhancing appearance.

Composite: Combining multiple ingredients to take advantage of their synergistic properties such as tragacanth-locust bean blends which offer better physical and barrier properties.

Applications of Edible Films and Coatings

Common uses include preserving fruits, vegetables, meats, bakery products and dry foods. Specific applications include Plastic, Paper, Glass, Metals

13.2.12. Membrane Processing:

Membrane processing is a separation technology widely used in industries such as food, dairy, pharmaceutical, biotechnology and waste water treatment. It employs semipermeable membranes to selectively allow the passage of certain molecules while blocking others based on size, charge, or chemical properties. Membrane processes are efficient, environmentally friendly and energy-saving compared to conventional separation methods. Types of membrane processes can be broadly classified into different types based on driving force and the nature of separation.

Micro Filtration (MF): It has a fore size of 0.1-10 µm and operating pressure of 50-500 Kpa. Removal of bacteria suspended solids and fat globules in good and dairy industries. Microfiltration membranes are used to clarify liquids, separate bacteria from milk and fractionate proteins. It is a low-pressure and is often used as a pretreatment for ultra filtration.

Ultra Filtration (UF): It has a pore size of 100 NM and operating Measure of 100 - 700 Kpa. 1-100 Concentration and purification of proteins removal of viruses and macromolecules and waste water treatment. Ultra filtration is commonly used in dairy industries to concentrate whey protein and produce protein-rich products. It also helps in reducing lactose content in milk.

Nano Filtration (NF): It has pore size of 1- 10 NM and operating pressure of 400-4000 Kpa. Removal of divalent and larger monovalent ions, lactose concentration and partial desalination. Nano filtration is used in water treatment to remove hardness and organic matter while retaining beneficial minerals. It also plays a significant role in demineralizing when in dairy processing. Reverse Osmosis (RO): It has pore size of <1nm and operating pressure of 2000-6000 Kpa. Water desalination, waste water recycling and concentration of the liquid foods. Reverse Osmosis allow only water molecules to pass through making them ideal for desalination and purification processes in the food, pharmaceutical and beverage industries.

Membrane Applications in Fruit Juice and Beverage Production:

Micro filtration and ultra filtration are the economic and efficient alternatives to the classical filtration methods available for clarification of different juices. The use of membrane processing in beverage industry has advantages like improved product quality, reduced cost of production.

Membrane Application in Dairy Processing:

Dairy industry is one of the early adaptors of the Membrane processes. It has greatly benefited by membranes as a number of applications like removal of water or concentration liquid-liquid as performed well as solid-liquid separations are routinely performed.

13.2.13. Hurdle Technology:

Introduction:

Hurdle technology foods are defined as products whose shelf life and the microbiological safety are extended by use of several factors none of which individually would be totally lethal towards spoilage or pathogenic microbes (Berwel, 1994).

Hurdle technology is a set of methods used for inactivation of microorganism in food preservation. Now-a-days combinations of methods or hurdle technology are employed for the preservation of food products.

Potential Hurdle Technology for Use in Preservation of Foods

Physical Hurdles:

High temperature (sterilization, pasteurisation, blanching) low temperature (chilling and freezing) U.V radiation, ionizing radiation, electromagnetic radiation,(microwave energy, radio frequency or oscillation magnetic field pulses and high electric field pulses photodynamic inactivation, ultrahigh pressure ultra sonication packaging film (plastic, multi layer, active coating, edible coating, modified atmosphere packaging gas vacuum, moderate vacuum and active packaging) aseptic packaging and food micro structure.

Physico-Chemical Hurdle: Low water activity (aW), Low PH, Low redox potential (Eh), salt (Nacl), Nitrate, CO2, O2, O3, organic acids, lactate, acetic acid, acetate, ascorbic acid, sulphite, smoking, phosphates, glucono-lactone, phenols, chelators, ethanols, propylene glycol, mailard reaction products, spices, herbs, lacto peroxidase and lysozyme.

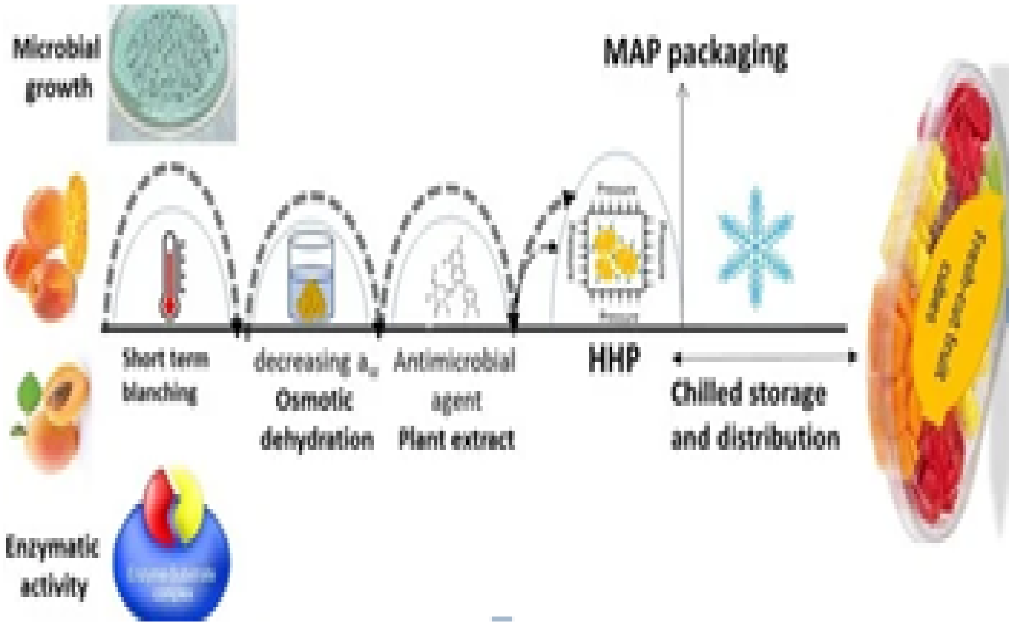


Fig. 13.2.10: Hurdle Technology

Advantages of Hurdles Technology:

A food product is microbiological stable and safe because of hurdles that is specific for the particular product in terms of the nature and strength of their effect. Together those hurdles keep spoilage or pathogenic microorganisms under control. This leads to the development of food that is shelf stable, superior, high quality and with fresh like characters. Furthermore, this approach is no single targeted but multi targeted.

There is every possibility that different hurdles in food will have additive or synergistic effect.

13.3. SUMMARY:

Novel food processing and preservation methods such as pulsed X-rays, microwave/radio frequency treatments, minimal processing, edible coatings, membrane processing and hurdle technology focus on enhancing food safety, quality and shelf life while preserving nutritional content. These techniques often rely on non-thermal methods to eliminate harmful microorganisms and reduce spoilage while maintaining the foods natural characteristics. Edible coatings and films provide protective barriers and membrane processing uses selective filtration to concentrate nutrients. Hurdle technology combines multiple preservation methods for effective results with minimal chemicals. These advanced methods offer sustainable alternatives to traditional processing, meeting consumer demand for clean-label, minimally processed foods. However, challenges remain in optimizing these technologies for consistency and ensuring regulatory approval for widespread use. Overall, these innovations improve food quality and safety while extending shelf life.

13.4. TECHNICAL TERMS:

Irradiation, High Pressure Processing (HPP), Pulsed Electric Fields (PEF), Microwave Processing, Radio Frequency (RF) Processing, Minimal Processing, Membrane Processing, Edible Coatings, Nanotechnology, Hurdle Technology.

13.5. SELF-ASSESSMENT QUESTIONS:

1) What is the primary advantage of using pulsed X-rays or microwave/radio frequency treatments in food processing?
2) How does hurdle technology enhance food preservation, and what are the key components involved in this approach?
3) In what ways do edible coatings and films contribute to food safety and quality?
4) What are the potential benefits and challenges associated with minimal processing techniques in food preservation?

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LESSON-14

NANOTECHNOLOGY AND APPLICATION IN FOODS

14.0 OBJECTIVES:

After going through this lesson students will understand

- To understand the concept of nanotechnology and its applications in food products, focusing on enhancing quality and functionality.
- To explore the various applications of nanotechnology in food processing such as packaging, preservation and texture/flavor improvement.
- To assess the benefits and risks of nanotechnology in food including its impact on safety, regulation and consumer acceptance.

STRUCTURE:

14.1. INTRODUCTION

Nanotechnology refers to the manipulation and control of matter at the nanoscale typically within the range of 1 to 100 nanometers. In food processing, this technology is applied to enhance various aspects of food production, preservation, packaging and quality. By working at the molecular level, nanotechnology enables the creation of new materials, tools and techniques that can significantly improve food safety, extend shelf life, enhance nutritional content and optimize processing methods. The application of nanotechnology in food processing is still emerging but holds great potential to revolutionize the industry.

In food processing, nanotechnology can be used to create more efficient processing methods, improve food texture and flavor, enhance the bioavailability of nutrients and develop smarter packaging solutions. For instance, nano encapsulation can protect sensitive nutrients like vitamins or antioxidants allowing them to be more effectively absorbed by the body. Nanomaterials can also be used to create active packaging that can detect contaminants or extend food shelf life. As the technology progresses, nanotechnology promises to contribute to more sustainable food systems by reducing waste, increasing efficiency and improving the overall quality of food products.

Nanotechnology advances in food processing are primarily focused on improving food texture, encapsulating food additives or ingredients, generating novel tastes and sensations, regulating flavour release and enhancing the bioavailability of nutrient content. Nanotechnology is used to innovate and improve food stuff and commodities throughout food processing and production, applying many typing of nano techniques and their applications.

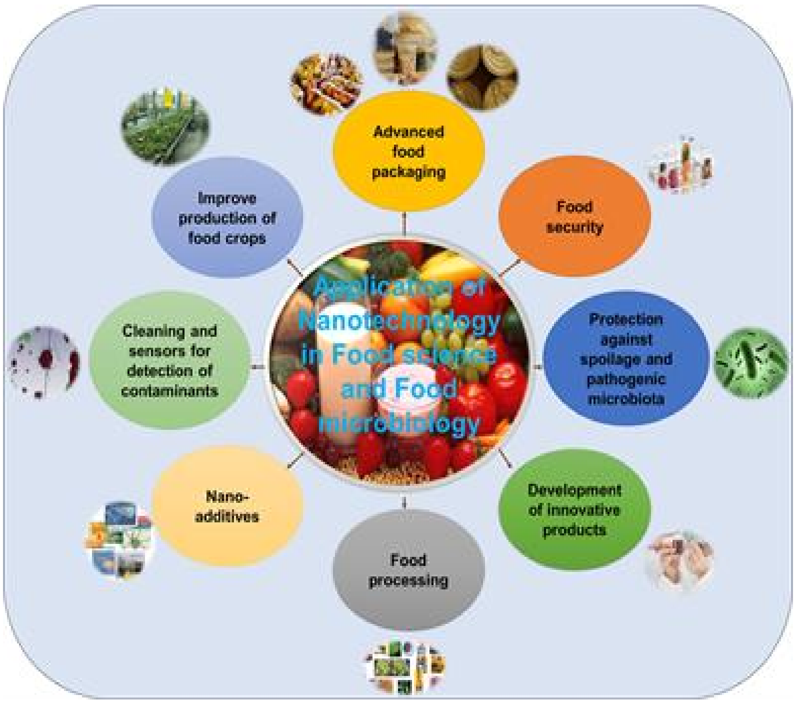


Fig. 14.1: Applications of Nanotechnology in Foods

14.2. Applications of Nanotechnology in Foods:

Nanotechnology has many applications in food including food packaging, food additives and food sensors. Here are some applications for Nanotechnology according to the Nanotechnology initiative.

- Food processing
- Food packaging
- Supplements
- Food additives
- Food sensors

14.2.1. Food Processing:

In food processing, nanotechnology enhances the functional and nutritional value of foods. Nanoencapsulation is widely used to improve the bioavailability of nutraceuticals, such as embedding vitamins and antioxidants in nano-sized capsules to ensure they are protected and efficiently absorbed by the body. Nanocapsulated flavor enhancers help retain and release flavors in a controlled manner, improving taste and aroma. Nanotubes and nanoparticles serve as thickening or gel-modifying agents helping to modify the texture of food.

Plant-based steroid nano infusions are used as a healthier alternative to cholesterol in meat products. Furthermore, nanoparticles can be used to selectively bind and remove harmful chemicals or pathogens from food enhancing food safety. Nanoemulsions improve the dispersion and availability of nutrients in food products making them more effective and stable.

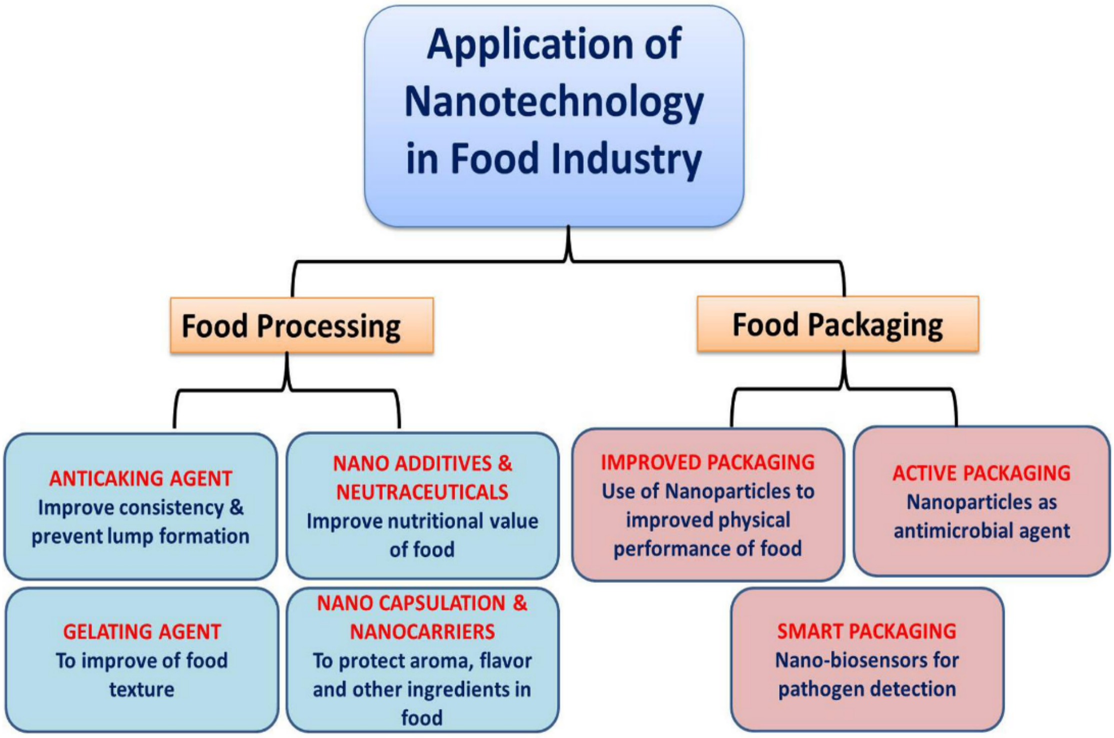


Fig. 14.2: Applications of Nanotechnology in Food Industry

14.2.2. Food Packaging:

Food packaging is one of the most important areas where nanotechnology has made a significant impact. Nano particles can be incorporated into packaging materials to create active or intelligent packaging systems. For example, antibodies can be attached to fluorescent nano particles to detect food borne pathogens, offering a fast and accurate method of contamination detection.

Biodegradable nano sensors can be embedded in packaging to monitor temperature, moisture and the passage of time ensuring food safety throughout the supply chain. Nano clays and nanofilms are used as barrier materials to prevent oxygen, light or moisture from spoiling the food. Electrochemical nanosensors can detect gases like ethylene which is involved in the ripening of fruits. Antimicrobial surface coatings using silver, magnesium or zinc nanoparticles help prevent bacterial and fungal growth. Additionally, silicates nanoparticles help make packaging films lighter, stronger and more resistant to heat.

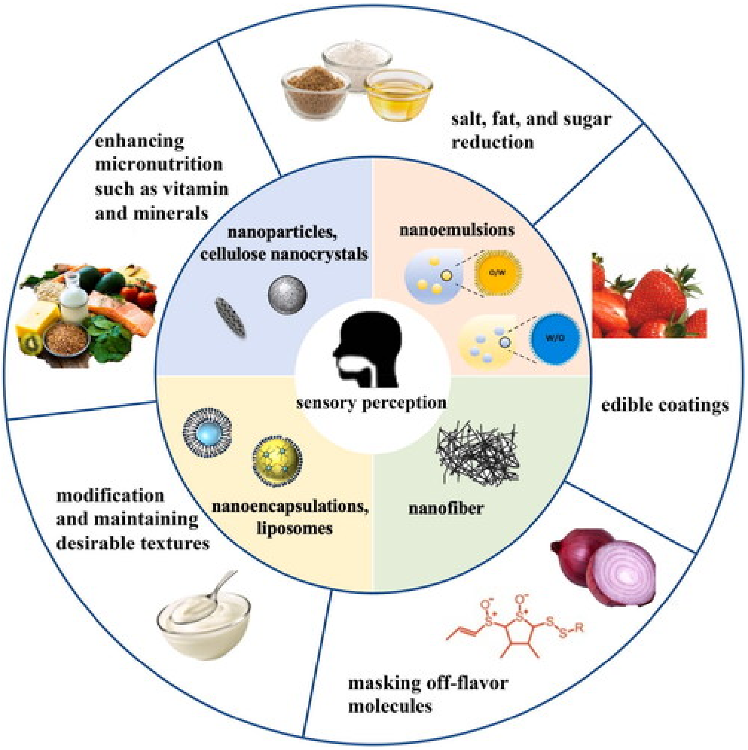
14.2.3. Supplements:

Nanosized powders to increase absorption of nutrients. Cellulose nanocrystal composites as drug carriers.

Nano capsulation of nutraceuticals for better absorption better stability or targeted delivery.

Nanocochelates (coiled nanoparticles) to deliver nutrients more efficiently to cells without affecting colour or taste of food.

Vitamin sprays dispersing active molecules into nanodroplets for better absorption.



14.2.4. Food Additives:

Nano capsules improve nutrient absorption and prolong shelf life. Antimicrobial agents protect food from bacterial deterioration. Anti- caking agents: improving the texture and appearance of food. Food additives in nanotechnology are used to improve food quality and including flavour, colour, texture and preservation. They can also improve nutrient bioavailability and absorption.

14.2.5. Nanominerals:

Nano minerals or nanoparticles of minerals are sometimes used in food products to improve texture, stability, appearance or nutrient absorption. Here are some commonly used nano minerals in food and examples of foods that may contain them.

Nanominerals are minerals that have been processed into particles at the nanoscale typically between 1 and 100 nanometers. Reducing minerals to this tiny size significantly enhances their solubility, absorption and bioavailability in the human body. Nanotechnology enables these essential nutrients to be better incorporated into food products particularly in fortified foods, dietary supplements and functional beverages.

The small size of nanominerals allows for greater surface area improving their interaction with biological systems. As a result, the body can absorb and utilize a higher percentage of the mineral compared to traditional larger mineral particles. They also tend to be more stable, less reactive and more easily blended into various food matrices without altering taste or texture.

Functions and Advantages of Nanominerals in Food:

- **Improved Nutrient Absorption:**

  Traditional minerals often have low bioavailability due to poor solubility or interference with other dietary components. Nanominerals however, can be absorbed more efficiently ensuring better nutritional outcomes.

- **Enhanced Stability:**

  Nanominerals are less prone to clumping, degradation or chemical reactions especially during food processing or storage. This leads to more consistent delivery of nutrients over the product's shelf life.

- **Better Texture and Appearance:**

  Due to their small size, nanominerals can be incorporated into foods without affecting mouth feel or causing grittiness. This makes them ideal for powdered mixes, beverages and smooth-textured products.

- **Functional Benefits:**

  Some nanominerals like nano silver or nano zinc also provide antimicrobial properties contributing to food safety and shelf-life extension when used in packaging or coatings.

Common Nanominerals Used in Food and Their Purposes:

Nano Calcium

Purpose: Supports bone and dental health; enhances calcium absorption.

Foods: Fortified dairy products, plant-based milks, fruit juices and supplements.

Benefit: Provides an easily absorbable form of calcium for individuals with dietary deficiencies.

Nano Iron

Purpose: Prevents iron-deficiency anaemia and supports energy metabolism.

Foods: Fortified bread, cereals, infant formula and nutritional powders.

Benefit: Improved solubility and reduced metallic taste compared to traditional iron fortificants.

Nano Zinc

Purpose: Boosts immune function and supports cell repair.

Foods: Fortified cereals, supplements, beverages.

Benefit: Higher absorption and additional antimicrobial effects in food packaging.

Nano Selenium

Purpose: Acts as an antioxidant and supports thyroid function.

Foods: Functional foods and dietary supplements.

Benefit: Enhanced antioxidant protection and improved nutrient delivery.

Nano Silver

Purpose: Known for its strong antimicrobial properties; not a nutritional supplement but used in food safety applications.

Foods: Not added directly to food in most cases but used in food packaging, coatings, or containers to prevent microbial contamination.

Benefit: Helps extend shelf life and prevent spoilage.

Nano Titanium Dioxide (TiO_2)

Purpose: Used as a whitening agent and to improve texture and opacity.

Foods: Candies, chewing gum, dairy and some baked goods (although its use is now restricted or banned in some countries due to health concerns).

Benefit: Enhances the visual appeal of food products though its safety is under scrutiny.

Nano Silicon Dioxide (SiO_2)

Purpose: Functions as an anti-caking agent to prevent clumping in powdered foods.

Foods: Instant soups, powdered spices, coffee creamers.

Benefit: Maintains flow and consistency in dry food products.

14.2.6. Nanovitamins:

Nano vitamins are vitamins that have been engineered at the nanoscale typically within the size range of 1 to 100 nanometres to enhance their solubility, stability, absorption and bioavailability in the human body. These nano-sized formulations are increasingly used in functional foods, fortified beverages and dietary supplements to deliver essential nutrients more effectively.

When vitamins are reduced to the nanoscale they gain a significantly higher surface area to volume ratio which allows for better interaction with biological membranes in the digestive system. This improves their uptake into the bloodstream, especially for vitamins that are normally poorly absorbed due to their water-insoluble or fat-soluble nature.

Purpose and Benefits of Nano Vitamins in Food Products

- **Enhanced Bioavailability:**

  Many traditional vitamin supplements have low absorption rates meaning the body only uses a small fraction of the consumed dose. Nano vitamins help overcome this limitation by penetrating cell membranes more efficiently and being better absorbed in the gastrointestinal tract.

- **Improved Stability:**

  Nano encapsulation of vitamins protects them from environmental conditions such as heat, oxygen, light and moisture that can degrade them during processing or storage. This results in a longer shelf life and more stable nutrient delivery in food products.

- **Controlled or Targeted Release:**

  Nano vitamins can be engineered for timed or targeted release, allowing nutrients to be delivered to specific parts of the body (e.g., the intestines) or released slowly over time for sustained effects.

- **Masking of Taste or Odour:**

  Some vitamins such as B-complex vitamins or certain minerals have unpleasant tastes or smells. Nano encapsulation helps to mask these characteristics making them easier to include in food and beverages without affecting sensory quality.

Common Nano Vitamins and Their Applications in Foods:

Nano Vitamin C (Ascorbic Acid):

Purpose: Enhanced antioxidant effects, immune support and collagen production

Food Uses: Fortified juices, sports drinks, dietary supplements and energy bars.

Benefit: Greater stability and absorption compared to traditional forms

Nano Vitamin D:

Purpose: Supports calcium absorption and bone health.

Food Uses: Fortified milk, plant-based alternatives, orange juice and supplements.

Benefit: Improved solubility, especially important since Vitamin D is fat-soluble.

Nano Vitamin A:

Purpose: Supports vision, immunity and skin health.

Food Uses: Fortified cereals, margarine, infant formula and dairy.

Benefit: Maintains potency in products exposed to air and light.

Nano Vitamin E (Tocopherol):

Purpose: Provides antioxidant protection to cells and tissues.

Food Uses: Fortified oils, cereals and nutritional beverages.

Benefit: Better protection against oxidative damage and increased absorption.

Nano Vitamin B12:

Purpose: Essential for red blood cell production and nerve function.

Food Uses: Nutritional yeast, energy bars, fortified drinks and supplements.

Benefit: Greater stability in food matrices and improved bioavailability.

Nano Vitamin K:

Purpose: Important for blood clotting and bone metabolism.

Food Uses: Fortified dairy, functional foods and dietary supplements.

Benefit: Enhanced delivery of this fat-soluble vitamin in aqueous environments.

Nano Multivitamins:

Purpose: Combined delivery of multiple essential vitamins and minerals.

Food Uses: Sports drinks, meal replacement shakes, and energy bars.

Benefit: Comprehensive nutrition in a compact, easily absorbed form.

Nano vitamins represent a major advancement in nutritional science, especially in the development of functional foods products designed not just to nourish but to improve health and reduce disease risk. By ensuring more efficient delivery and effectiveness of essential nutrients nano vitamins help bridge the gap between diet and health, especially in populations with nutrient deficiencies or specific dietary needs.

Moreover, their integration into a wide range of food products from beverages to cereals enables manufacturers to fortify everyday foods without compromising taste, texture or appearance. This makes it easier for consumers to meet their daily nutritional requirements passively as part of their regular diet.

14.2.7. Nanoliposomes:

Nano liposomes are widely used in the food industry to encapsulate bioactive compounds improving their stability, solubility and bioavailability. They help protect sensitive nutrients from degradation due to heat, light and oxygen while enhancing their absorption in the body.

Nanoliposomes are tiny vesicles composed of lipid bilayers that exist at the nanoscale, typically less than 200 nanometers in diameter. They are used to encapsulate bioactive compounds such as vitamins, antioxidants, polyphenols, essential oils, probiotics and proteins in food products. These nano-sized lipid-based carriers are designed to protect sensitive ingredients, improve their stability and enhance their absorption and bioavailability in the human body.

Nanoliposomes function by surrounding the bioactive compound with a lipid membrane creating a barrier that shields the compound from environmental stressors such as heat, light, oxygen and enzymatic degradation. This encapsulation ensures that the compound remains effective until it reaches its target in the digestive system.

Applications of Nanoliposomes in Food Products:

- **Encapsulation of Vitamins and Antioxidants**:

  Nanoliposomes are widely used to encapsulate water- and fat-soluble vitamins such as Vitamin C, Vitamin E, and Vitamin A. These vitamins are prone to degradation during processing and storage. Encapsulation protects them and allows for better absorption in the gastrointestinal tract. For example, fortified juices and dairy products often use nanoliposomal Vitamin C and E to preserve antioxidant properties.

- **Delivery of Polyphenols and Plant Extracts**:

  Plant-derived compounds like curcumin (from turmeric), resveratrol (from grapes), and catechins (from green tea) have powerful antioxidant and anti-inflammatory effects. However, their poor solubility and instability limit their effectiveness. Nanoliposomes improve their solubility, shelf life and biological availability when added to functional beverages, health drinks and energy bars.

- **Omega-3 Fatty Acids and Essential Oils**:

  Oils such as fish oil, flaxseed oil and essential oils (e.g., oregano, thyme, cinnamon) are highly sensitive to oxidation which can result in undesirable odors and loss of nutritional value. Nanoliposomes encapsulate these oils to prevent oxidation, mask unpleasant flavours and ensure they are delivered effectively to the body. These are found in fortified dairy, spreads and drinks.

- **Probiotics and Peptides**:

  Beneficial bacteria like *Lactobacillus* and *Bifidobacterium* as well as bioactive peptides are encapsulated using nanoliposomes to survive harsh conditions in the stomach and reach the intestines. These formulations are used in yogurt, fermented milk products and nutritional supplements to enhance gut health and digestive function.

- **Encapsulation of Proteins and Amino Acids**:

  Functional foods often use nanoliposomes to carry proteins such as whey and casein and amino acids like branched-chain amino acids (BCAAs). These are especially popular in sports nutrition products and meal replacement drinks where faster and more efficient absorption is needed.

- **Colorants and Flavors**:

  Natural food colorants such as curcumin and carotenoids are encapsulated in nanoliposomes to improve colour stability in products exposed to light and oxygen. Similarly, flavours like vanilla, citrus oils or fruit essences are encapsulated to prevent evaporation and degradation ensuring long-lasting taste in processed foods and confectionery.

Benefits of Nanoliposomes in Food Industry:

Enhanced Stability: Protects sensitive compounds from oxidation, heat, light and pH changes. Improved Solubility: Helps incorporate water-insoluble compounds into food matrices. Increased Bioavailability: Enhances the absorption and utilization of nutrients in the body. Controlled Release: Allows for sustained or targeted release of nutrients over time.

Flavor Masking: Masks undesirable tastes or odors of bioactive compounds.

Extended Shelf Life: Improves the overall stability and storage time of functional foods.

Examples of Nano Liposomes in Food Products:

Encapsulation of Vitamins & Antioxidants:

Vitamin C & E: Used in fortified juices and dairy products to prevent oxidation.

Curcumin: Found in functional beverages and supplements to enhance bioavailability. Polyphenols (from green tea, grapes, or berries): Used in health drinks and energy bars for improved antioxidant effects.

Omega-3 Fatty Acids & Essential Oils:

Fish oil & flaxseed oil: Added to dairy products, spreads and functional drinks to mask taste and prevent oxidation.

Essential oils (e.g., thyme, oregano, cinnamon): Used in food preservation due to their antimicrobial properties.

Probiotics & Peptides:

Lactobacillus and Bifidobacterium: Encapsulated for use in yogurt, fermented drinks and dietary supplements to enhance gut health.

Bioactive peptides: Found in dairy and protein-based beverages for functional nutrition.

Food Colorants & Flavors:

Curcumin & carotenoids: Used in sauces, dairy and beverages for color stability. Encapsulated flavors (e.g., vanilla, citrus oils): Improve taste retention in processed foods and candies.

Proteins & Amino Acids:

Whey and casein proteins: Used in sports nutrition products and meal replacement drinks.

Branched-chain amino acids (BCAAs): Found in protein shakes for enhanced absorption.

Benefits of Using Nano Liposomes in Foods:

Enhanced stability of bioactive compounds, improved solubility and absorption in the body, controlled release for prolonged effects, masking of undesirable flavours and odors, extended shelf life of functional food products.

14.2.8. Food Sensors:

Nano sensors detect harmful components in food such as pathogens, contaminates allergens. Food sensors developed using nanotechnology play a crucial role in ensuring food quality, safety and freshness throughout the supply chain from production to consumption. These nanosensors are capable of detecting minute changes in the environment or in the food itself thanks to their high sensitivity, specificity and rapid response times.

Nanosensors are designed to identify harmful components such as pathogens, contaminants, toxins, allergens and even indicators of spoilage or degradation. By working at the molecular or atomic level these sensors can detect extremely low concentrations of undesirable substances making them ideal tools for maintaining strict food safety standards.

One of the primary applications of food nanosensors is the detection of pathogens. Harmful bacteria such as *Salmonella*, *Escherichia coli* (E. coli) and *Listeria monocytogenes* can cause severe food borne illnesses. Nanosensors embedded in packaging or applied in testing devices can quickly identify these pathogens often before visible signs of spoilage occur. These sensors often use biological recognition elements such as antibodies or DNA probes linked to nanoparticles which generate a detectable signal when a specific pathogen is present.

Nanosensors are also used to determine the freshness of food products. During spoilage chemical compounds such as amines, ethanol or sulfur-containing gases are released. Nanosensors can detect these spoilage indicators in real time giving consumers and suppliers an accurate idea of product freshness. For example, color-changing indicators in packaging can signal if meat or dairy has gone bad.

Another critical application is monitoring packaging conditions. Smart packaging systems with embedded nanosensors can track environmental factors like temperature, humidity, light exposure and time. If perishable items are exposed to temperatures outside the safe range the nanosensor can trigger a warning—either through visual indicators or via digital alerts. This ensures that cold chain integrity is maintained during storage and transportation.

In addition to physical conditions, nanosensors can also detect toxins and chemical contaminants. These include pesticide residues heavy metals (like lead or mercury) and industrial pollutants. Such sensors help in quality control and regulatory compliance by ensuring that food products remain within safe chemical limits.

Allergen detection is another vital function. Trace amounts of allergens like peanuts, gluten or shellfish proteins can be harmful to sensitive individuals. Nanosensors can identify even tiny quantities of allergenic proteins helping manufacturers prevent cross-contamination and improve product labeling accuracy.

Finally, nanosensors are used to monitor degradation and shelf life. They can identify metabolites produced during food decomposition or fermentation helping assess whether food is still safe to consume. These sensors contribute to reducing food waste by providing more precise shelf-life assessments rather than relying solely on conservative expiry dates.

Nanosensors have transformed food monitoring by offering precise, real-time and on-site detection of a wide array of food safety and quality parameters. Their integration into food packaging and quality control processes not only enhances food safety but also builds consumer trust, reduces food waste and increases overall efficiency in the food supply chain.

Nanotechnology based sensors are used in food safety and quality control to detect contaminants, allergens and freshness. They can also used to monitor food packaging.

Detect pathogens: Nanosensors can detect pathogens like salmonella and e-coli.

Determine freshness: Nanosensors can detect freshness, ripeness and microbial contamination.

Monitor packaging: Nanosensors can used in packaging to monitor food safety and quality.

Detect toxins: Nanosensors can detect toxins and other chemicals pollutants.

Detect degradation: Nanosensors can detect degradation metabolites and allergens.

14.3. SUMMARY:

Nanotechnology is being applied in food processing, packaging, supplements, additives and sensors to improve food quality, safety and nutrition. In food processing, it helps enhance nutrient absorption, improve flavor and remove harmful pathogens. In packaging, nanotechnology is used for better spoilage prevention, antimicrobial properties and detection of contaminants. Nano-sized minerals and vitamins improve nutrient bioavailability in fortified foods. Nanoliposomes encapsulate bioactive compounds like vitamins and antioxidants, boosting their effectiveness. Food sensors based on nanotechnology monitor food freshness, detects pathogens and ensure food safety. These innovations help create healthier, more convenient and sustainable food products.

14.4. TECHNICAL TERMS:

Food processing, Food packaging, Supplements, Food additives, Food sensors, nanoliposomes.

14.5. SELF-ASSESSMENT QUESTIONS:

1) How can nanotechnology be applied to food packaging to extend shelf life?
2) What are the potential benefits of nanotechnology in enhancing the texture and flavor of food?
3) How do nanomaterials contribute to food packaging and what are some specific examples of their use?
4) What role do nanoliposomes play in improving the stability and bioavailability of bioactive compounds in food products?

14.6. REFERENCE BOOKS:

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LESSON-15

FOOD PRODUCTS: DEFINITION, CHARACTERISTICS AND NEED FOR NEW FOOD PRODUCT DEVELOPMENT. CLASSIFICATION: LINE EXTENSIONS - REPOSITIONING OF EXISTING PRODUCTS

15.0 OBJECTIVES:

After going through this lesson students will understand

- To Understand the Definition and Characteristics of New Food Products
- To Explore the Need for New Food Product Development (NPD)
- To Examine Classification Strategies: Line Extensions and Repositioning

STRUCTURE:

15.1. INTRODUCTION

New food product development (NPD) is the process through which new food products are created or existing products are improved to meet evolving consumer demands, technological advancements and market trends. As consumer preferences shift toward healthier, more convenient and sustainable options, food companies must continuously innovate to stay competitive. NPD encompasses several stages, including idea generation, product formulation, testing and market introduction. The need for new food products arises from the growing demand for products that cater to specific dietary needs, provide enhanced nutrition or offer functional benefits.

Classifying new food products includes strategies like line extensions where variations of existing products (such as new flavors or formulations) are introduced and repositioning, which involves changing the market perception or target audience of an existing product. Both strategies allow companies to expand their offerings and address consumer needs without starting from scratch, helping them maintain their competitive edge in the dynamic food industry.

A new food product can be defined as any food item that is newly created, reformulated, enhanced or introduced to a new market. This includes products that offer improved nutrition, unique flavors, greater convenience or better packaging. The concept of new food products is not limited to brand-new inventions; it also encompasses line extensions, repositioning of existing products and reformulations that better align with modern needs.

These products are characterized by innovation, consumer-focused design, improved nutritional value, technological integration and alignment with food safety and sustainability standards. The primary aim of developing new food products is to respond to consumer needs, expand market share, improve health outcomes and contribute to a more sustainable food system.

Two major classifications in the development of new food products include:

Line Extensions: These are variants of an existing product introduced in different flavors, sizes, packaging formats or nutritional compositions under the same brand name.

Repositioning of Existing Products: This involves changing the product's image, target audience or marketing strategy to meet new consumer expectations or adapt to emerging market trends without altering its core composition.

15.2. NEW FOOD PRODUCT

A new food product refers to any food item that has been recently developed, reformulated, improved or repositioned to meet the changing needs and expectations of consumers. It encompasses both completely novel innovations and modifications of existing food items designed to enhance their sensory appeal, nutritional quality, convenience or marketability. The process of new food product development involves integrating scientific innovation, technological advancements and consumer insight to create foods that align with current trends in health, sustainability and lifestyle.

The primary objective of developing new food products is to help food companies remain competitive in the rapidly evolving marketplace, expand product portfolios and capture emerging market segments. It also allows manufacturers to address specific concerns such as health consciousness, dietary restrictions, environmental sustainability and demand for convenience foods.

New food products are not always entirely novel inventions; they can also arise from modifications or reintroductions of existing foods to serve different purposes or appeal to new audiences. Depending on the level of innovation and purpose new food products can be broadly classified into the following categories:

Line Extensions:

These involve adding new variants such as flavors, colors, sizes or packaging formats to an already existing product line.
Example: Launching a mango flavor of an existing yogurt brand or introducing snack packs of the same product.

- **Reformulated Products:**

  Reformulation focuses on modifying the composition of an existing product to improve its nutritional profile, shelf life or consumer appeal. This includes reducing fat, sugar or sodium content or making the product gluten-free or lactose-free. *Example:* Sugar-free beverages, low-fat dairy products or fortified breakfast cereals.

- **Technological Innovations:**

  These products utilize advanced technologies or novel processing methods to enhance product quality, functionality or sustainability.

  Example: 3D-printed foods, nanotechnology-enhanced products and plant-based meat alternatives developed through extrusion technology.

- **Functional Foods:**

  These are foods designed to provide additional health benefits beyond basic nutrition, often through fortification, enrichment or incorporation of bioactive components. *Example:* Omega-3 enriched eggs, probiotic yogurts and antioxidant-rich beverages.

Culturally Adapted or Localized Products:

These are traditional or regional foods modified to suit the taste preferences, dietary habits or regulations of international or local markets.

Example: Low-spice versions of Indian curries for Western markets or fusion snacks that blend Asian and Western flavors.

Convenience Foods:

With changing lifestyles, consumers increasingly prefer foods that save time and effort. This category includes ready-to-eat, ready-to-cook or instant meal options. *Example:* Frozen meals, instant soups and microwaveable rice.

Sustainable and Eco-Friendly Products:

Modern consumers are becoming environmentally conscious, leading to innovations that focus on sustainability, reduced packaging waste and plant-based ingredients. *Example:* Edible cutlery, biodegradable packaging and products made from up cycled food ingredients.

The development of a new food product is a multi-stage process involving idea generation, prototype development, sensory evaluation, market testing and commercialization. Each stage requires collaboration among food scientists, technologists, marketers, nutritionists and quality control experts to ensure the final product is safe, appealing and economically viable.

Fig. 15.1: New Product Development

15.2.1. Characteristics of a New Food Product:

Innovation:

New food products often involve innovative concepts, ingredients or production techniques.

Examples include plant-based meat alternatives, fortified beverages and probiotic-enriched foods. Developed based on detailed market research and consumer preferences. Focused on meeting specific needs such as health, taste, convenience, dietary restrictions or ethical concerns.

Consumer Appeal:

A successful new food product must align with consumer preferences such as organic, gluten-free or functional foods that provide health benefits.

Convenience foods, ready-to-eat meals and snack bars with natural ingredients cater to busy lifestyles.

Nutritional Value:

Consumers are increasingly seeking foods that support health and wellness.

Many new products are fortified with vitamins, minerals, fiber or probiotics to enhance their nutritional profile.

Shelf Stability:

New food products must maintain quality over time while ensuring safety and freshness.

Advances in packaging and preservation techniques such as modified atmosphere packaging (MAP) and high-pressure processing (HPP), help extend shelf life.

Safety & Quality:

Food safety regulations ensure that new products meet hygiene, processing and labeling standards.

Quality assurance measures are essential to maintain taste, texture and consistency.

Sustainability:

Consumers are increasingly aware of environmental impacts, driving demand for sustainable food products.

Innovations in plant-based alternatives, eco-friendly packaging and responsible sourcing contribute to a product's sustainability.

Technological Innovation:

Utilizes advanced food processing technologies like:

Nanoencapsulation, High-pressure processing, Freeze-drying, Smart packaging aims to increase shelf life, stability and product safety while retaining quality.

Convenience and Ease of Use:

Tailored for modern lifestyles with options like:

Ready-to-eat meals, Single-serve portions, Microwaveable packaging, Meal kits and functional drinks

Compliance with Food Regulations:

Must adhere to national and international food safety standards.

Labelling, health claims, allergens and ingredient declarations must meet regulatory norms.

Market Differentiation:

New products must offer something unique or improved to stand out in a competitive market either through: Branding, Unique selling proposition (USP), Superior health benefits, Cultural significance.

15.2.2 Need for New Food Product Development:

The development of new food products is essential for the growth, innovation and sustainability of the food industry. With the global food market rapidly evolving, consumers are increasingly demanding foods that are healthier, safer, more convenient and environmentally responsible. Companies must therefore continuously innovate to meet these demands while maintaining profitability and compliance with regulatory standards.

The major factors driving the need for new food product development include:

1. Changing Consumer Preferences:

Consumer attitudes and lifestyles are constantly changing, influencing the types of foods people choose to buy and consume.

- **Health and Wellness Awareness:**

  Increasing public awareness about the relationship between diet and health has shifted consumer preference toward nutrient-dense, low-calorie and functional foods. People now prefer foods that not only satisfy hunger but also contribute to overall health such as high protein snacks, probiotic beverages and foods fortified with vitamins and minerals.

- **Demand for Special Diets:**

  Modern consumers often follow specific dietary patterns such as plant-based, ketogenic, gluten-free, vegan or lactose-free diets due to health conditions or personal choices. This trend has encouraged manufacturers to innovate using alternative ingredients like almond milk, soy protein, millet flour, quinoa and pea protein.

- **Convenience and Lifestyle Changes:**

  Urbanization and busy lifestyles have increased demand for ready-to-eat (RTE), ready-to-cook (RTC), and on-the-go foods that save time without compromising nutrition. Examples include instant oatmeal cups, meal-replacement shakes and snack bars.

2. Market Competition:

The food industry is one of the most dynamic and competitive sectors globally. To maintain brand recognition and consumer loyalty, companies must continually innovate.

- **Product Differentiation:**

  Launching new or improved products helps companies stand out in the market and prevent consumer fatigue from repetitive offerings.

  Example: Ice cream brands releasing limited-edition flavors or fusion varieties (like chocolate chilli or turmeric latte).

- **Expanding Market Share:**

  By introducing new flavors, packaging formats or product categories, companies can target new demographic groups such as children, athletes or senior citizens.

- **Responding to Competitor Innovations:**

  When one company launches a successful new product, competitors often follow with similar or improved alternatives such as the wave of plant-based meat substitutes that followed the success of Beyond Meat and Impossible Foods.

3. Technological Advancements:

Modern technology plays a pivotal role in revolutionizing the food industry by improving efficiency, quality, safety and creativity in product development.

- **Innovations in Processing and Preservation:**

  Techniques like high-pressure processing (HPP), freeze-drying, microwave-assisted pasteurization and ultrasound processing help create foods with better texture, taste and extended shelf life.

- **Smart Packaging Technologies:**

  The use of active and intelligent packaging enables better preservation, freshness indicators and reduced spoilage.

  Example: Time–temperature indicator (TTI) labels on perishable foods.

- **Emerging Technologies:**

  Cutting-edge innovations such as 3D food printing, nano-encapsulation of nutrients and the use of artificial intelligence (AI) in product formulation and consumer trend prediction have transformed product development.

  Example: AI tools are now used to create optimal flavor combinations or design recipes for personalized nutrition.

4. Health and Nutrition Trends:

Rising global health issues have encouraged consumers to make more mindful food choices, prompting companies to reformulate or develop healthier alternatives.

- **Prevention of Lifestyle Diseases:**
  The increasing prevalence of obesity, diabetes, cardiovascular diseases and hypertension has driven the demand for low-fat, low-sodium and low-sugar foods.
- **Functional and Fortified Foods:**
  Consumers are drawn to foods that offer additional health benefits such as cholesterol-lowering spreads, antioxidant-rich drinks, protein-enriched biscuits or calcium-fortified juices.
- **Clean Label Movement:**
  There is growing interest in transparency and natural ingredients leading to the creation of products free from artificial colours, preservatives and additives. *Example:* Products labelled "No Preservatives" or "100% Natural Ingredients" have become more common in supermarkets.

5. Sustainability and Ethical Concerns:
Sustainability has become a key driver of innovation in the food sector, as both consumers and regulators emphasize environmentally responsible practices.

- **Eco-Friendly Production:**
  Food industries are adopting green technologies, reducing carbon footprints and minimizing food waste during processing and distribution.
- **Sustainable Ingredients:**
  Manufacturers are exploring plant-based proteins, algae, insect-based flours and lab-grown meat as sustainable alternatives to conventional animal-based ingredients.
- **Ethical Sourcing and Packaging:**
  The use of biodegradable packaging materials, recyclable containers and fair-trade certified ingredients appeals to environmentally conscious and socially responsible consumers.
  Example: Fair-trade coffee, cocoa and tea products ensure ethical treatment of farmers and workers.

6. Regulatory Requirements:
Government regulations and global food safety standards significantly influence product formulation and labelling. Compliance often necessitates the development of new or reformulated products.

- **Changing Food Safety and Libelling Laws:**
  Food safety authorities such as **FSSAI (India)**, **FDA (USA)** and **EFSA (Europe)** regularly update guidelines regarding permissible additives, nutritional labelling, and health claims. To adhere to these, companies must modify their product compositions. *Example:* Reduction of Trans fats and sodium content in processed foods to comply with WHO recommendations.
- **Allergen and Intolerance Awareness:**
  The growing recognition of food allergies (e.g., gluten, nuts, dairy) has driven the introduction of allergen-free alternatives such as gluten-free bread and dairy-free ice cream.
- **Nutrition Policy Initiatives:**
  Some governments encourage food reformulation as part of public health policies for instance programs promoting fortification of flour with iron or salt with iodine to prevent micronutrient deficiencies.

15.3. Classification: Line Extensions:

15.3.1. Introduction:

In the competitive world of marketing, businesses constantly evolve their products to meet consumer demands, stay relevant and increase profitability. Three key strategies used for product development and adaptation include Line Extensions, Repositioning of Existing Products and New Forms of Existing Products. Each of these strategies serves a unique purpose in helping brands maintain or expand their market share. This document explores these strategies in detail, highlighting their significance, benefits, challenges and real-world examples.

15.3.2. LINE EXTENSIONS

A line extension occurs when a company expands an existing product line by introducing new variations, such as different flavors, colors, sizes, ingredients or packaging styles. This strategy allows businesses to target new customer segments while leveraging the established reputation of an existing brand.

Purpose:

To capitalize on the popularity of an existing product.

To offer more choices to consumers.

To increase market share by targeting new consumer segments.

Examples of Line Extensions:

- **Coca-Cola Variants:** Coca-Cola introduced Diet Coke, Coke Zero and flavoured versions such as Cherry Coke and Vanilla Coke to cater to different consumer preferences.

- **Lays Potato Chips:** Lays expanded its product line with flavors like Barbecue, Sour Cream & Onion and Spicy Chilli to attract diverse customer segments.
- **Colgate Toothpaste:** Colgate offers variations like Colgate Total, Colgate Sensitive and Colgate Herbal to address different oral care needs.
- **Amul:** Extended its range with Amul Taaza, Amul Gold, Amul Kool and flavored ice creams to serve varied consumer groups.
- **Maggi:** Launched Atta Noodles, Oats Noodles and Hot Heads as healthier and spicier alternatives.
- **Pepsi:** Added Pepsi Diet, Pepsi Black and flavours like Lime and Vanilla to offer calorie-free and flavoured options.
- **Britannia:** Expanded with Good Day (Butter, Cashew, Choco chip), Marie Gold Lite, and Treat (Jim Jam, Choco Creme) for all age groups.
- **Kellogg's:** Introduced Chocos, All-Bran and Special K for both children and health-conscious consumers.
- **Cadbury Dairy Milk:** Extended to Silk, Fruit & Nut, Crackle, Oreo and Lickables to provide flavor and texture variety.
- **Mother Dairy:** Offered Belgian Chocolate, Kesar Pista and sugar-free ice creams for health-focused buyers.
- **Haldiram's:** Added Moong Dal, Navratan Mix and Khatta Meetha to its namkeen range to attract varied snack consumers.
- **Frooti/Appy (Parle Agro):** Introduced Frooti Fizz and Appy Fizz to target youth seeking fizzy fruit-based drinks.
- **KitKat:** Expanded into Dark, White, Chunky and Matcha variants to cater to flavor innovation.
- **Bingo! (ITC):** Extended to Mad Angles, Tedhe Medhe and Hashtags with unique shapes and Indian-inspired flavors.

Benefits of Line Extensions: Brand Loyalty Enhancement: Providing more options keeps customers engaged with the brand.

Increased Market Share: Helps in capturing new customer segments.

Cost Efficiency: Uses existing brand reputation, reducing marketing and R&D costs.

Competitive Advantage: Prevents competitors from gaining market dominance. Low risk, since the brand is already known. Reduced marketing costs due to brand recognition. Helps keep the product line fresh and competitive.

Fig. 15.2: Line Extensions

15.2.3 Repositioning of Existing Products:

Repositioning refers to the strategic process of altering the market perception of an existing product to make it more appealing to a new or changing customer base. It involves redefining the product's image, target audience, pricing strategy, packaging, promotional approach or value proposition to better align with current consumer expectations, market dynamics or competitive pressures.

This strategy is often employed when a product's sales begin to decline, the brand image becomes outdated or new market opportunities emerge. Instead of completely replacing the product, companies revitalize it through repositioning to extend its life cycle and enhance its relevance in a changing marketplace.

Repositioning can involve:

Updating the brand's image through new advertising themes or modernized packaging.

Highlighting different product attributes to fit emerging market trends such as sustainability, health or technology.

Purpose of Repositioning:

The main purposes of repositioning an existing product include:

To Revive Declining Sales:

When a product's sales start falling due to market saturation, outdated branding or changing consumer preferences, repositioning can renew interest.

Example: *Maggi* was repositioned as a convenient, quick meal for all age groups rather than just a children's snack.

To Target a New Demographic or Market Segment

Repositioning allows brands to reach a broader or entirely different audience by changing their message or appeal.

Example: *Old Spice* shifted its focus from older men to a younger generation through humorous advertising and influencer marketing.

To Align with Changing Consumer Trends and Values

Modern consumers prioritize health, sustainability and social responsibility. Repositioning helps brands stay relevant by aligning with these evolving values.

Example: *McDonald's* rebranded itself as a healthier, family-oriented restaurant by introducing salads, fruit bowls and low-calorie menu options.

To Respond to Technological or Lifestyle Changes

As lifestyles evolve and technology shapes consumer habits products must adapt their messaging or usage context.

Example: *Nike* repositioned itself to empower women athletes, launching dedicated campaigns and products for female consumers.

Branding and campaigns to reflect youth, energy and pop culture trends.

Examples of Repositioning:

- **McDonald's:** McDonald's shifted its branding from a fast-food chain to a healthier alternative by introducing salads, fruit options and healthier ingredients.
- **Old Spice:** Originally marketed for older men, Old Spice repositioned itself as a trendy brand for younger men through humorous advertising and modern packaging.

- **Nike's Focus on Women:** Nike expanded its target audience by repositioning itself to appeal more strongly to female athletes through dedicated marketing campaigns and product lines.
- **Maggi (Nestlé):** Originally positioned as a quick snack for kids, Maggi was repositioned as a convenient meal option for all age groups.
- **Cadbury Dairy Milk:** Initially seen as a children's chocolate, Cadbury repositioned it as a treat for all occasions and age groups.
- **Tata Tea:** Repositioned from a simple beverage to a socially conscious brand.
- **Surf Excel:** Changed from a detergent brand focused on stain removal to one promoting emotional values.
- **Domino's Pizza:** Repositioned from a fast-food brand to a family-friendly quick-service brand with the tagline *"30 Minutes or Free."*
- **KFC:** Shifted from a fried chicken brand to one offering diverse locally adapted meals, including vegetarian and grilled options to attract Indian consumers.
- **Pepsi:** Transitioned from a rebellious youth drink to a fun, energetic lifestyle brand linked with sports and entertainment.
- **Amul:** Repositioned from just a dairy brand to an emotional witty symbol of Indian culture.
- **Paper Boat:** Repositioned from a beverage product to an emotion-driven brand evoking nostalgia with traditional Indian drinks like Aam Panna.

Strategies Used:

New advertising campaigns targeting different age groups or lifestyles.

Packaging to look more modern or health-focused.

Changing the product name or tagline to reflect new usage.

Fig. 15.3 (A): Examples of Repositioning

Fig. 15.3 (B): Examples of Repositioning

Expands Customer Base:

Helps brands reach new markets, demographics or psychographic segments by appealing to different consumer needs and lifestyles. Generates renewed interest in existing products, attracting both new and returning customers, thereby boosting profitability. Gives mature or declining products a new lease of life without the need for complete redevelopment, keeping them relevant for longer periods. Ensures the product remains relevant amid changing consumer preferences, technological advances or cultural trends. Strengthens Brand Image improves brand perception, aligns with modern values and enhances emotional connection with consumers through updated messaging and design.

Competitiveness: Allows companies to stay competitive in dynamic markets by differentiating from rivals and responding quickly to new opportunities.

Encourages Brand Loyalty: Renewed consumer engagement strengthens trust and loyalty, leading to sustained brand preference.

Cost-Effective Strategy: More economical than launching an entirely new product, as it utilizes existing brand equity, infrastructure, and distribution networks.

Supports Market Evolution: Facilitates alignment with emerging trends such as health consciousness**,** sustainability**,** and ethical consumption**.**

Improves Overall Brand Portfolio: A successful repositioning enhances the company's entire product portfolio, improving overall brand strength and long-term market presence.

15.5. SUMMARY:

New Food Product Development (NPD) is essential in the food industry to meet evolving consumer demands, technological advancements, and market trends. NPD involves creating new products or improving existing ones to cater to consumer needs for health, convenience, sustainability, and innovation. Characteristics of successful new food products include innovation, consumer appeal, nutritional value, shelf stability, safety, quality, and sustainability. The need for NPD arises from changing consumer preferences, market competition, health trends, sustainability concerns, and regulatory requirements.

NPD strategies include line extensions-expanding an existing product line with new variations, and repositioning, where an existing product is rebranded or targeted to a new market segment. Other approaches include reformulation (changing product ingredients for health or compliance reasons), new packaging (to improve functionality or sustainability), and the development of innovative products (such as plant-based meats or personalized nutrition). Each strategy aims to enhance a brand's appeal, increase market share, and stay competitive in the dynamic food industry.

15.6. TECHNICAL TERMS:

New Food Product Development (NPD), Line Extensions, Reformulation, Repositioning.

15.7. SELF-ASSESSMENT QUESTIONS:

1) What is the primary difference between line extensions and repositioning of food products?
2) Why is new food product development important for staying competitive in the food industry?
3) What are some of the key stages involved in new food product development?

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LESSON-16

NEW FORM OF EXISTING PRODUCT - REFORMULATION - NEW PACKAGING INNOVATIVE PRODUCTS - CREATIVE PRODUCTS AND VALUE-ADDED PRODUCTS

16.0 OBJECTIVES:

After going through this lesson students will understand

- To learn about new forms of existing products and how they meet consumer needs.
- To understand how reformulation improves food products' health benefits and taste.
- To explore the role of innovative packaging in extending shelf life and sustainability.

STRUCTURE:

16.1. INTRODUCTION

The food industry is constantly evolving to meet changing consumer demands, technological advancements and market trends. To stay competitive, companies adopt various strategies to enhance or adapt existing products. These strategies include introducing new forms of existing products, reformulating products to improve nutritional value, using innovative packaging techniques and creating value-added or creative products. New forms of existing products cater to modern lifestyles, while reformulation focuses on improving health benefits or meeting regulatory requirements. Innovative packaging ensures product longevity and sustainability, while value-added and creative products focus on offering enhanced features such as added nutritional benefits or unique flavor combinations. Together, these strategies help companies stay relevant, attract new consumers and maintain a competitive edge in the dynamic food market.

16.2. NEW FORMS OF EXISTING PRODUCTS

This strategy involves introducing a product in a new format while maintaining its core function. It allows brands to cater to changing consumer preferences and modern lifestyles.

A new form of an existing product refers to a product that retains the core ingredients or composition of an already established product but is reformulated, restructured or repackaged into a different physical form to provide added convenience, improved functionality or appeal to a different market segment.

This type of innovation focuses on changing the product format such as from solid to liquid, from powder to ready-to-drink or from large size to bite-sized portions without changing the basic identity of the product.

Examples of New Forms of Existing Products:

Bar Soap to Liquid Body Wash: Many soap brands like Dove and Lux introduced liquid body washes.

Instant Coffee Variants: Traditional coffee brands introduced instant coffee powders, pods, and capsules for convenience.

Tablet to Effervescent Form: Brands like Vitamin C supplements transitioned from pills to effervescent tablets for easier consumption. A traditional dairy-based yogurt offered in a drinkable form for on-the-go consumption. Converting tea leaves or tea bags into ready-to-drink iced tea bottles. A regular protein bar reformulated into protein powder or protein cookies. A large-sized cake or dessert reintroduced as single-serve or mini portions. Instant noodles repackaged into microwavable cups for added convenience.

Purpose and Advantages:

- **Convenience**: Catering to busy lifestyles by offering easier preparation or portable formats.
- **Targeting new audiences**: Attracting consumers who prefer different product experiences (e.g., children, athletes, health-conscious individuals).
- **Extending product use occasions**: Making the product suitable for different consumption scenarios such as travel, school or work.
- **Improved functionality**: Enhancing shelf life, mixing ability or ease of use through reformulation.
- **Market differentiation**: Setting the product apart from competitors by offering a novel experience.

- **Challenges & Considerations:** While these strategies provide numerous benefits, they also come with challenges such as: High marketing and R&D costs, Risk of brand dilution, Consumer resistance to change, Competition from existing and emerging brands.

16.3. REFORMULATION:

In the food industry, companies constantly adapt to consumer needs, technological advancements and market trends. Three key strategies that drive growth and improve product offerings are Reformulation, New Packaging and Innovative Products. These approaches allow companies to stay competitive, cater to health-conscious consumers, reduce environmental impact,and provide more convenient solutions.

16.3.1. Introduction:

Reformulation involves changing the ingredients, nutritional profile or composition of an existing food product to meet evolving consumer demands, regulatory requirements or health trends. Reformulation can help improve the product's taste, nutritional value or health benefits while maintaining its appeal and consistency.

Examples of Reformulation:

- **Reducing Sugar –** Soft drink manufacturers reformulating recipes to lower sugar content replacing it with artificial sweeteners or natural sugar substitutes. Reformulating sugary beverages to be low-calorie by using stevia or other non-nutritive sweeteners. Replacing hydrogenated oils with trans-fat-free oils in baked goods. Reformulating dairy products to create lactose-free or plant-based versions. Switching to natural food colours and flavours in candies or soft drinks.
- **Fortification –** Adding vitamins, minerals or fibre to products like breakfast cereals, bread or milk to meet consumer demand for healthier functional foods.
- **Reducing Sodium –** Reformulating processed foods like snacks and canned soups to lower sodium content for health-conscious consumers.
- **Plant-Based Alternatives –** Reformulating dairy products to include plant-based ingredients like almond or oat milk, catering to vegan and lactose-intolerant consumers.

16.3.2. Advantages of Reformulation:

Healthier Options Meets consumer demand for nutritious, low-calorie, and functional foods. Regulatory Compliance Helps meet evolving food safety, nutrition labelling, and environmental regulations. Maintaining Brand Loyalty provides healthier alternatives without losing the core identity of the product. Meets consumer demand for healthier and cleaner-label products. Enhances product marketability and competitiveness. Supports brand reputation by aligning with public health goals. Adapts to emerging health trends and legislation. Reduction of allergens (e.g., gluten-free or nut-free versions)

16.4. NEW PACKAGING:

New packaging refers to changing the design, material or functionality of a product's packaging to improve its appeal, convenience or sustainability. Packaging plays a crucial role in attracting consumers, preserving food quality and minimizing environmental impact.

Examples of New Packaging:

Eco-Friendly Packaging – Brands using biodegradable, recyclable, or compostable materials for packaging to reduce plastic waste and appeal to environmentally conscious consumers.

Smart Packaging – Packaging with built-in sensors to monitor freshness, spoilage or temperature changes often seen in perishable items like dairy or meat. Convenience Packaging Single-serve portions or reselable packs for easy access and to extend product freshness (e.g., snack packs or meal kits). Transparent Packaging – Clear packaging that allows consumers to see the product inside increasing trust and appeal. Switching from glass to lightweight PET bottles for beverages. Introducing resealable zip-lock pouches for snacks or cereals. Using biodegradable trays or compostable packaging in frozen foods. Designing single-serve or portion-controlled packs for on-the-go eating. Eco-friendly/biodegradable packaging from bamboo, corn starch, or seaweed. Tamper-proof and child-safe closures. QR codes for digital engagement product origin, recipes, or allergen information.

Fig. 16.1: New Packaging Materials

16.4.1. Advantages of New Packaging:

Improved Shelf Life – Packaging designed to protect food quality, reduce spoilage and extend freshness.

Consumer Appeal – Eye-catching and functional packaging attracts more customers. Sustainability – Meets increasing consumer demand for environmentally friendly, reusable and recyclable packaging. Boosts consumer satisfaction and loyalty. Enhances product visibility and differentiation on store shelves. Reduces transportation and storage costs through lightweight materials. Aligns with growing demand for eco-friendly and sustainable products. Improves brand communication and educational outreach through smart labelling.

16.5. INNOVATIVE PRODUCTS:

Innovative products refer to entirely new food concepts or the introduction of unique combinations, ingredients or production methods that have not been widely available in the market. These products often push boundaries catering to emerging consumer trends and advancements in food technology.

Innovative products are entirely new-to-the-world or highly differentiated food products that introduce a novel idea, ingredient, technology, formulation or consumption experience that did not previously exist in the market. These products are designed to meet emerging consumer needs, solve specific problems or deliver unique value propositions through creativity, research and advanced technology.

Unlike line extensions or reformulations, innovative products often involve a significant departure from traditional products and can even create a new product category in the food industry.

16.5.1. Key Characteristics:

- **Originality**: Not just a variation but a completely new concept or feature.
- **Novel Ingredients or Techniques**: Use of unique materials, biotechnology or nanotechnology.
- **Consumer-Centric**: Solves unmet needs, aligns with future trends or fills a gap in the market.
- **Market Differentiation**: Offers strong distinction from competitors.
- **Often Patentable**: May involve proprietary processing methods or ingredients.

16.5.2. Examples of Innovative Products:

Plant-Based Meat Alternatives Products like Beyond Meat and Impossible Burger, which mimic real meat using plant proteins and heme molecules, offer a novel solution for vegetarians and sustainability-focused consumers. Lab-Grown or Cultured Meat Meat produced directly from animal cells in lab conditions, aimed at reducing animal slaughter and environmental impact. 3D-Printed Foods Personalized meals produced through 3D printing technology using edible ingredients, ideal for healthcare, hospitality or futuristic dining experiences. Functional Beverages with Probiotics and Adaptogens Drinks enriched with gut-friendly bacteria, mushrooms, or botanical extracts that enhance immunity, focus or relaxation. Edible Water Pod Biodegradable pods that encapsulate water or flavored drinks using seaweed-based packaging, eliminating the need for plastic bottles. Smart Food with Embedded Sensors Foods with embedded nanosensors that signal freshness, nutrient content, or contamination in real-time. Allergen-Free Alternatives Chickpea- or algae-based egg substitutes, milk made from peas, oats or hemp, and nut-free spreads that offer safe choices for allergy sufferers. Food-as-Medicine Products Products specifically formulated to manage health conditions such as diabetes, high blood pressure, or cholesterol integrating nutrition with therapeutic intent.

Personalized Nutrition – Food products tailored to individual nutritional needs based on genetic information or specific health goals (e.g., meal plans or supplements).

16.5.3. Benefits of Innovative Products:

Market Leadership: Brands that launch innovative products often become trendsetters.

Attracts Early Adopters: Especially among health-conscious, tech-savvy and sustainability focused consumers.

Solves Unmet Needs: Addresses gaps that current food products do not fulfil.

Brand Value & Prestige: Enhances the brand’s image as forward-thinking and modern.

Creates New Categories: Opens up opportunities for entirely new market segments and sales channels.

16.5.4. Challenges:

High R&D Cost and Time: Developing something truly innovative can be expensive and time-consuming.

Market Acceptance: Consumers may resist unfamiliar formats or ingredients.

Regulatory Approval: New technologies and ingredients may require rigorous safety assessments and legal clearances.

Scalability: Mass production may be difficult or expensive at early stages.

Fig. 16.2: Innovative Products

16.5.5. Advantages of Innovative Products:

Differentiation – Helps brands stand out in competitive markets with unique offerings. Meeting Consumer Demands – Responds to trends like plant-based diets, sustainability and functional foods.

Market Expansion – Creates new food categories, tapping into emerging markets and consumer bases.

16.6. Creative Products:

Creative products in the food industry refer to new, innovative food concepts or combinations that push boundaries, appeal to emerging trends and cater to specific consumer desires. These products stand out due to their uniqueness in taste, appearance, ingredients or preparation methods, often blending different cultures, textures or flavors to create exciting, unexpected food experiences. Creative products refer to food items developed through the imaginative use of ingredients, design, flavor combinations or presentation styles that result in a unique or surprising consumer experience. Unlike purely functional innovations, creative products often emphasize novelty, aesthetics, sensory appeal and emotional connection with consumers. They may not always involve new technology or complex formulations but they are distinguished by their inventiveness and originality in concept, form or consumption experience.

16.6.1. Key Characteristics:

- **Visually Unique**: Artistic or unconventional shapes, colors or plating styles.
- **Unusual Combinations**: Unexpected pairings of flavors or textures.
- **Culturally Inspired**: Fusions of ingredients or dishes from different culinary traditions.
- **Emotionally Engaging**: Evokes curiosity, joy, nostalgia or surprise.
- **Experience-Oriented**: Offers more than just taste—often includes storytelling, interactive elements or themed presentations.

16.6.2. Examples of Creative Products:

Fusion Foods – Combining elements from different cuisines to create innovative dishes, such as sushi burritos, taco pizzas or Korean BBQ burgers.

Novel Flavors – Unique flavor combinations, like lavender honey ice cream, spicy chocolate or pickle-flavoured chips, catering to adventurous palates.

Plant-Based Innovations – Creative products like plant-based seafood (e.g., seaweed-based tuna alternatives) or dairy-free cheese made from nuts and legumes.

Snack Innovations – Unconventional snack forms, like protein-packed chips, cricket flour-based protein bars or vegetable-based crisps.

Functional Beverages – Drinks infused with ingredients like CBD, adaptogens or nootropics, combining health benefits with flavor such as functional sparkling waters or kombucha with superfoods.

For Examples:

Sushi Burritos, Dessert Tacos, Black Garlic Chocolate or Chili Mango Candy Deconstructed Dishes, Colour-changing drinks DIY kits for kids Pop culture or event-themed foods Interactive foods Fusion desserts.

Fig. 16.3: Creative Products

16.6.3. Benefits of Creative Products:

High Consumer Engagement: Fun shareable experiences that appeal to emotions.

Social Media Buzz: Visually striking or imaginative items are highly shareable online.

Brand Differentiation: Sets a brand apart through uniqueness and storytelling.

Broad Appeal: Especially effective with children, foodies and trend-conscious youth. Flexibility: Can be applied to both premium and affordable product lines.

16.6.4. Challenges:

Short Product Life Cycle: Some creative trends may be seasonal or fad-based. Cost of Presentation: Aesthetic packaging or styling may increase production cost.

Limited Mass Market Appeal: Some consumers prefer traditional food styles.

Consistency: Replicating artistic or complex designs at scale can be challenging.

16.6.5. Advantages of Creative Products:

Differentiation – Helps brands stand out by offering unique or novel products not available in the market.

Appeal to Trendsetters – Attracts adventurous consumers interested in new experiences and flavors.

Engagement – Sparks curiosity and interest among consumers, encouraging trial and repeat purchases.

16.7. VALUE-ADDED PRODUCTS:

Value-added products are food items that have been enhanced in some way to increase their quality, convenience, functionality or appeal, adding extra value to the raw ingredients or the original product. These products offer additional benefits, making them more desirable to consumers, whether in terms of nutritional content, packaging or convenience.

Value-added products are foods that have been modified, enhanced or processed to increase their market value, consumer appeal or functional benefits beyond their raw or basic state. This can include changes in form, function, nutrition, packaging, shelf life, convenience or branding, all aimed at offering more value to the consumer. Value addition typically transforms a basic commodity into a more desirable product, leading to higher profitability and better consumer satisfaction.

Fig. 16.4: Value-Added Products

16.7.1. Key Characteristics:

Enhanced Quality or Functionality: Nutritional enrichment, improved shelf life or better taste. Convenience-Oriented: Easy-to-use, ready-to-eat (RTE) or ready-to-cook (RTC) formats. Processed or Packaged Differently: Cut, mixed, frozen, vacuum-packed or fortified.

Consumer-Centric Design: Offers solutions to specific consumer needs such as health, time-saving, or sustainability.

Higher Market Value: Sells at a premium compared to its raw form.

16.7.2. Examples of Value-Added Products:

Fortified Foods – Foods enriched with added vitamins, minerals, fiber, or protein to enhance nutritional value. For example, fortified breakfast cereals, calcium-enriched plant-based milk, or high-protein snack bars.

Pre-Packaged Convenience Foods – Ready-to-eat or ready-to-cook meals, such as microwaveable rice, pre-washed salads or meal kits that offer time savings and ease of preparation.

Organic and Fair-Trade Products – Foods that offer consumers ethical choices, such as organic fruits and vegetables, fair-trade chocolate or sustainably sourced seafood.

Reduced Fat/Sugar Options – Products that have been reformulated to reduce fat or sugar content, catering to health-conscious consumers, like low-sugar sauces, fat-free snacks or diet-friendly desserts.

Functional Foods – Foods designed to provide health benefits beyond basic nutrition, such as probiotic yogurt, gut-health drinks or energy-boosting smoothies.

Seasonal variants—mango-flavoured products in summer, pumpkin spice in autumn

Cultural positioning—heritage-inspired foods like millet cookies or ancient grain breads

Extended use formats—e.g., tomato paste in squeezable bottles with longer shelf life

Nutrient-enriched staples—e.g., folic acid-fortified wheat flour for maternal health

16.7.3. Benefits of Value-Added Products:

Increased Profit Margins: Higher retail price than raw materials.

Market Differentiation: Offers brands a competitive edge.

Consumer Convenience: Saves time and effort in preparation.

Reduces Waste: Preserving perishable items adds value and reduces food loss.

Supports Farmer Income: Processing at the farm level boosts rural economies.

Caters to Specific Markets: Such as health-conscious, children or aging populations.

16.7.4. Challenges:

Initial Investment in Equipment & Processing: Requires infrastructure for transformation. Shorter Shelf Life for Some Products: Especially semi-processed or natural variants.

Market Acceptance: Consumers may need education or awareness for newer forms.

Quality Assurance: Higher consumer expectations demand consistent quality and safety.

Fig. 16.5: Value-Added Products

16.7.5. Advantages of Value-Added Products:

Enhanced Marketability – Value-added products can be marketed based on their additional health benefits, convenience or ethical sourcing.

Increased Profit Margins – By adding features like fortification, convenience or ethical certification, these products can command higher prices.

Consumer Loyalty – Offering products that cater to health, sustainability and convenience trends can attract repeat customers and build brand loyalty.

16.8. SUMMARY:

The food industry continuously evolves by introducing new forms of existing products, reformulating recipes, using innovative packaging and creating value-added or creative products. Strategies such as changing a product's format or composition allow companies to meet shifting consumer preferences, address health concerns and respond to market trends. For example, reformulating products to reduce sugar fortify with vitamins or replace animal ingredients with plant-based alternatives helps meet consumer demand for healthier and more sustainable options. New packaging solutions such as eco-friendly materials or smart packaging also cater to the growing consumer focus on sustainability and convenience.

Innovative products push the boundaries of food technology, offering entirely new food concepts or unique combinations to capture emerging trends like plant-based diets or functional foods. Creative products on the other hand, blend different culinary traditions or ingredients to appeal to adventurous consumers. Value-added products enhance basic foods by offering additional benefits like nutritional fortification or convenience, thus improving marketability and consumer loyalty. These strategies collectively enable brands to differentiate themselves in a competitive market and stay relevant to changing consumer demands for health, convenience and sustainability.

16.9. TECHNICAL TERMS:

Eco-Friendly Packaging, Repositioning, New Packaging, Innovative Products, Creative Products, Value-Added Products

16.10. SELF-ASSESSMENT QUESTIONS:

1) What are the benefits of introducing new forms of existing products? Provide an example.
2) How does reformulation contribute to meeting consumer demand for healthier food options?
3) What role does innovative packaging play in enhancing consumer appeal and sustainability?
4) Explain the difference between creative products and value-added products in the food industry?

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LESSON-17

PACKAGING MATERIALS: DEFINITION, IMPORTANCE AND SCOPE OF PACKAGING OF FOODS, ORIGIN OF PACKAGING MATERIALS

17.0 OBJECTIVES:

After studying this unit, you should be able to

- Outline the importance of packaging;
- Describe importance and scope of packaging of foods;
- State the origin of packaging materials.

STRUCTURE:

17.1. INTRODUCTION

Packaging plays a prominent role in the modern food industry by ensuring the safe delivery of food products from producers to consumers. Food packaging can be defined as the method of enclosing food items in suitable materials to protect them from contamination, physical damage, and spoilage while maintaining their quality and extending shelf life. The importance of packaging lies not only in preservation and protection but also in facilitating handling, providing information, enhancing convenience, and serving as a medium for marketing and branding. The scope of food packaging extends across multiple sectors-from agriculture and food processing to logistics and retail-using a wide range of materials such as paper, plastic, metal, glass, and biodegradable alternatives. The origin of packaging materials dates back to ancient times, where natural elements like leaves, clay, and animal skins were used. Over time, with industrial advancements, materials evolved to include glass, tin, and plastics, and more recently, innovations have focused on sustainable and intelligent packaging solutions. Understanding the development and multifunctional role of packaging is essential for ensuring food safety, consumer satisfaction, and environmental sustainability in today’s global food systems.

17.2. DEFINITION OF PACKAGING MATERIALS

Packaging materials are the substances used to create containers or wrappers that enclose, protect, and preserve products - particularly food items - during storage, shipment or transportation, and distribution at optimum cost, compatible with the requirements of the product. These materials are selected based on their ability to provide a physical barrier against contamination, maintain product quality, and support handling and marketing functions. Common packaging materials include paper, plastic, glass, metal, and biodegradable alternatives, each chosen for specific protective, mechanical, and environmental properties.

In simple terms, any physical material that is used to cover, wrap, seal, or hold a product is called a packaging material. The main purpose is to protect the item, especially food, and keep it safe and fresh. The choice of packaging material depends on the type of food being packaged. It also includes deciding the right kind of packaging equipment and making sure the package is properly labeled with the necessary information.

17.3 IMPORTANCE OF PACKAGING OF FOODS

Packaging plays a important role in the food industry as it helps ensure that food remains safe, fresh, and suitable for consumption. Proper packaging protects food from contamination, spoilage, physical damage, and environmental factors such as moisture, light, and air. It also makes food easier to store, handle, and transport. In addition to protection, packaging provides important information about the product, such as its ingredients, manufacturing date, preparation methods, vegetarian or non-vegetarian, expiry date, and usage instructions. Attractive packaging can also helps in marketing by catching the attention of consumers. With growing awareness about safety, hygiene, convenience, and sustainability, the role of packaging has become more important than ever in today’s food supply chain. Here’s a concise list of the importance of packaging materials:

1. Physical and Barrier Protection

- Prevents food from physical damage (crushing, breaking).
- Acts as a barrier against moisture, light, oxygen, dust, and microorganisms.
- Protects from chemical contamination during handling and transportation.

2. Preservation

- Helps in increasing the shelf life of food by slowing down spoilage.
- Prevents microbial growth and maintains food quality.
- Reduces food waste by keeping food fresh for longer periods.

3. Safe Storage and Transportation

- Makes it easier to stack and store food safely.
- Reduces chances of leakage or breakage during shipping.
- Ensures food reaches consumers in good condition.

4. Convenience

- Packaging provides easy handling, opening, pouring, resealing, and disposing.
- Ready-to-use packaging (e.g., microwavable containers, snack pouches) adds comfort to modern lifestyles.

5. Information and Labeling

- Packages display important product information like:
- Brand name
- Ingredients
- Nutritional facts
- Manufacturing and expiry dates
- Storage and cooking instructions
- Essential for consumer awareness and regulatory compliance.

6. Marketing and Branding

- Visually attractive packaging helps promote the product.
- Color, design, and logo help create brand identity.
- Packaging influences consumer buying decisions.

7. Hygiene and Safety

- Protects food from being touched, exposed, or tampered with.
- Some packaging includes tamper-evident features for consumer safety.
- Especially important for perishable and sensitive foods like dairy or baby food.

8. Standardization and Portion Control

- Packaging helps in delivering fixed quantities (e.g., 500g, 1L).
- Useful in food service, retail, and diet planning.

9. Legal Compliance

- Packaging ensures food is labeled as per government regulations.
- Important for food traceability, taxation, and product recalls.

10. Environmental Concerns and Sustainability

- Eco-friendly packaging helps reduce pollution and waste.
- New innovations focus on biodegradable, recyclable, and reusable materials.

17.4. SCOPE OF PACKAGING OF FOODS

In today‘s competition market condition, every food manufacturers should aware from packaging of food. Consumer wants new pattern with innovation design of package. Food manufacturers mainly focus on new trend about food packaging.

The scope of food packaging is wide and vital, covering everything from the transformation of raw ingredients into consumable food products to ensuring the safety, quality, and extended shelf-life of the final product. Food packaging is a important part of the food industry as it provides protection, maintains food quality, supports marketing, and meets consumer needs. Packaging also involves aspects of food science, technology, nutrition, and engineering, making it an interdisciplinary field that supports modern food production systems.

Food packaging goes beyond simply wrapping food-it is a combination of art, science, and technology that ensures food reaches consumers in the best possible condition.

In the modern world, packaging is no longer just a functional aspect of the product. It has evolved into a strategic tool for business success. Packaging is integral to product marketing, branding, and consumer satisfaction. In many ways, the success of a product is closely linked to how it is packaged.

Packaging serves a dual purpose: protection and promotion. While its primary function is to protect and preserve the product, it also serves as a powerful means of attracting customers, enhancing product appeal, and creating a memorable image.

Moreover, packaging plays an essential role in product storage, shipping, and sale, influencing everything from the logistics process to consumer perception.

17.4.1 Packaging as a Marketing Tool

17.4.1.1. Branding and Image Creation

- **Scope**: Packaging acts as the first point of interaction between the consumer and the product. How a product is packaged significantly influences the consumer’s perception of the brand and its values.
- **Marketing Impact**: A well-designed package communicates key attributes of the product and brand, such as quality, style, or premium status.

  Examples:

  - **Luxury Brands**: High-end cosmetic brands like Chanel use sleek, elegant packaging to convey exclusivity and sophistication.
  - **Eco-friendly Packaging**: Brands like Patagonia emphasize sustainable packaging, reinforcing their commitment to environmental responsibility.

17.4.1.2. Attraction and Visual Appeal

- **Scope**: Packaging designs are crafted to catch the consumer's attention, especially in crowded retail environments. Color, texture, and typography all contribute to the visual appeal of the product.
- **Marketing Impact**: The design of packaging can make the product stand out on the shelf, increasing its chances of being noticed and purchased.

  Examples:

  - **Snack Food Packaging**: Bright, colorful designs on bags of chips or candies often appeal to children and young adults.
  - **Beverages**: Unique bottle shapes, labels, and vibrant colors used by beverage companies like Coca-Cola or Red Bull create strong brand recognition.

17.4.1.3. Product Positioning and Differentiation

- **Scope**: Packaging allows products to be positioned in the market and differentiated from competitors. The design choices in packaging reflect the brand's story and values.
- **Marketing Impact**: Packaging communicates the target market for a product—whether it's a luxury good, a health-conscious item, or an affordable everyday product.

  Examples:

  - **Health-conscious Food**: Products like organic snacks or gluten-free products often use clear, simple, and green-themed packaging to convey health benefits.
  - **Mass-market Items**: Everyday household items may use simpler packaging but rely on recognizability and cost-effectiveness.

17.4.2 Packaging and Consumer Experience

17.4.2.1. First Impressions Matter

- **Scope**: When a consumer first encounters a product, the packaging creates an immediate impression of the product's quality and reliability.
- **Marketing Impact**: A product that is packaged neatly and securely creates an image of professionalism, increasing consumer trust and satisfaction.

  Examples:

  - **E-commerce Packages**: Customers who receive well-packaged products in the mail (e.g., from Amazon or Etsy) are more likely to feel positive about the brand, even before they experience the product itself.
  - **Food and Beverage**: Properly sealed, fresh-looking packages contribute to the idea that the food inside is of high quality.

17.4.2.2. Convenience and Functionality

- **Scope**: Packaging has evolved to focus on consumer convenience, which is a major factor in customer satisfaction.
- **Marketing Impact**: Consumers appreciate packaging that is easy to open, resealable, or suitable for storage and use.

  Examples:

  - **Microwaveable Meals**: Packaging that's designed to be microwave-safe and easy to open without additional tools.
  - **Snack Packaging**: Resealable snack bags ensure freshness and convenience, encouraging repeat purchases.

17.4.2.3. Customer Satisfaction and Retention

- **Scope**: The experience of receiving a product that is securely and thoughtfully packaged enhances customer satisfaction. A positive packaging experience can also influence customer loyalty and retention.
- **Marketing Impact**: Customer satisfaction is not just about the quality of the product; it's also about how well the product is presented and delivered. Packaging plays a critical role in this experience.

  Examples:

  - **E-commerce Packaging**: An attractive, sturdy package that includes a thank-you note or personalized touch can increase customer satisfaction and encourage positive reviews.
  - **Gift Packaging**: Special gift wrapping or packaging for items sold during holidays or special events can enhance the perceived value of the product and delight customers.

17.4.3 Technological Advancements in Packaging

17.4.3.1. Smart Packaging

- **Scope**: Technological innovations in packaging, such as the integration of **smart labels**, **QR codes**, and **temperature indicators**, help track the condition of the product and enhance consumer interaction.

  Examples:

  - **Smart Labels**: QR codes on food packaging allow consumers to check the source and nutritional content of products in real-time.
  - **Temperature Indicators**: These are used on products like pharmaceuticals or perishable foods to ensure the product has been stored within the safe temperature range.

17.4.3.2. Sustainability in Packaging

- **Scope**: With growing environmental concerns, many companies are focusing on sustainable packaging materials, such as biodegradable or recyclable options, to reduce environmental impact.
- **Marketing Impact**: Sustainable packaging can also be a powerful marketing tool, aligning the brand with eco-conscious consumers.

  Examples:

  - **Compostable Packaging**: Companies like Whole Foods and other organic brands use compostable or plant-based packaging.
  - **Recyclable Packaging**: Many beverage companies, such as Coca-Cola and PepsiCo, have committed to using 100% recyclable materials for their bottles and cans.

17.4.4 Packaging in E-commerce

17.4.4.1. The E-commerce Packaging Experience

- **Scope**: In the e-commerce world, packaging goes beyond protection to play a critical role in **customer experience** and **brand perception**.
- **Marketing Impact**: Packaging in e-commerce serves as the physical representation of the brand when it arrives at the consumer's door. A thoughtfully packaged item contributes to positive brand perception.

  Examples:

  - **Subscription Boxes**: Companies like Birchbox or Loot Crate use custom-designed boxes to delight customers with a unique unboxing experience.
  - **Amazon Packaging**: Packaging that protects the product and delivers it intact can help customers feel more confident in future purchases, while also aligning with Amazon’s branding.

17.4.4.2. Packaging and Return Process

- **Scope**: Packaging is also crucial for facilitating returns and exchanges in the e-commerce industry. Good packaging can make it easier for consumers to return items if needed.
- **Marketing Impact**: Providing easy-to-use return packaging can increase consumer trust and reduce frustration, contributing to higher customer retention.

  Examples:

  - **Prepaid Return Labels**: Many e-commerce companies now include a return label and packaging, making the return process as easy as possible.

17. 5 ORIGIN OF PACKAGING MATERIALS

Very early in time, food was consumed where it was found. Families and villages were self-sufficient, making and catching what they used. When containers were needed, nature provided gourds, shells and leaves to use. Later, containers were fashioned from natural materials, such as hollowed logs, woven grasses and animal organs.

Fabrics descended from furs used as primitive clothing. Fibers were matted into felts by plaiting or weaving. These fabrics were made into garments, used to wrap products or formed into bags. With the weaving process, grasses, and later reeds, were made into baskets to store food surpluses. Some foods could then be saved for future meals and less time was needed for seeking and gathering food.

Paper and Paper Products: Paper may be the oldest form of what today is referred to as "flexible packaging." Sheets of treated mulberry bark were used by the Chinese to wrap foods as early as the first or second century B.C. During the next 1,500 years, the paper making technique was refined and transported to the Middle East, then Europe and finally into the United Kingdom in 1310. Eventually, the technique arrived in America in Germantown, Pennsylvania, in 1690.

But these first papers were somewhat different from those used today. Early paper was made from flax fibers and later old linen rags. It wasn't until 1867 that paper originating from wood pulp was developed. Although commercial paper bags were first manufactured in Bristol, England, in 1844, Francis Wolle invented the bag making machine in 1852 in the United States. Further advancements during the 1870s included glued paper sacks and the gusset design. After the turn of the century (1905), the machinery was invented to automatically produce in-line printed paper bags.

With the development of the glued paper sack, the more expensive cotton flour sacks could be replaced. But a sturdier multi-walled paper sack for larger quantities could not replace cloth until 1925 when a means of sewing the ends was finally invented. The first commercial cardboard box was produced in England in 1817, more than 200 years after the Chinese invented cardboard. Corrugated paper appeared in the 1850s; about 1900, shipping cartons of faced corrugated paperboard began to replace self-made wooden crates and boxes used for trade.

As with many innovations, the development of the carton was accidental. Robert Gair was a Brooklyn printer and paper-bag maker during the 1870s. While he was printing an order of seed bags, a metal rule normally used to crease bags shifted in position and cut the bag. Gair concluded that cutting and creasing paperboard in one operation would have advantages; the first automatically made carton, now referred to as "semi-flexible packaging," was created.

The development of flaked cereals advanced the use of paperboard cartons. The Kellogg brothers were first to use cereal cartons at their Battle Creek, Michigan, Sanatorium. When this "health food" of the past was later marketed to the masses, a waxed, heat-sealed bag of Waxtite was wrapped around the outside of a plain box. The outer wrapper was printed with the brand name and advertising copy. Today, of course, the plastic liner protects cereals and other products within the printed carton. Paper and paperboard packaging increased in popularity well into the 20th century. Then, with the advent of plastics as a significant player in packaging (late 1970s and early 1980s), paper and its related products tended to fade in use. Lately, that trend has halted as designers try to respond to environmental concerns.

Glass: Although glass-making began in 7000 B.C. as an offshoot of pottery, it was first industrialized in Egypt in 1500 B.C. Made from base materials (limestone, soda, sand and silica), which were in plentiful supply, all ingredients were simply melted together and molded while hot. Since that early discovery, the mixing process and the ingredients have changed very little, but the molding techniques have progressed dramatically.

At first, ropes of molten glass were coiled into shapes and fused together. By 1200 B.C., glass was pressed into molds to make cups and bowls. When the blowpipe was invented by the Phoenicians in 300 B.C., it not only speeded production but allowed for round containers. Colors were available from the beginning, but clear, transparent glass was not discovered until the start of the Christian era. During the next 1000 years, the process spread steadily, but slowly, across Europe.

The split mold developed in the 17th and 18th centuries further provided for irregular shapes and raised decorations. The identification of the maker and the product name could then be molded into the glass container as it was manufactured. As techniques were further refined in the 18th and 19th centuries, prices of glass containers continued to decrease. One development that enhanced the process was the first automatic rotary bottle making machine, patented in 1889. Current equipment automatically produces 20,000 bottles per day. While other packaging products, such as metals and plastics, were gaining popularity in the 1970s, packaging in glass tended to be reserved for high-value products. As a type of “rigid packaging,” glass has many uses today.

Metals: Ancient boxes and cups, made from silver and gold, were much too valuable for common use. Other metals, stronger alloys, thinner gauges and coatings were eventually developed. The process of tin plating was discovered in Bohemia in A.D. 1200 and cans of iron, coated with tin, were known in Bavaria as early as the 14th century. However, the plating process was a closely guarded secret until the 1600s. Thanks to the Duke of Saxony, who stole the technique, it progressed across Europe to France and the United Kingdom by the early 19th century. After William Underwood transferred the process to the United States via Boston, steel replaced iron, which improved both output and quality.

In 1764, London tobacconists began selling snuff in metal canisters, another type of today's “rigid packaging.” But no one was willing to use metal for food since it was considered poisonous. The safe preservation of foods in metal containers was finally realized in France in the early 1800s. In 1809, General Napoleon Bonaparte offered 12,000 francs to anyone who could preserve food for his army. Nicholas Appert, a Parisian chef and confectioner, found that food sealed in tin containers and sterilized by boiling could be preserved for long periods. A year later (1810), Peter Durand of Britain received a patent for tinplate after devising the sealed cylindrical can.

Since food was now safe within metal packaging, other products were made available in metal boxes. In the 1830s, cookies and matches were sold in tins and by 1866 the first printed metal boxes were made in the United States for cakes of Dr. Lyon's tooth powder. The first cans produced were soldered by hand, leaving a 1 1/2-inch hole in the top to force in the food. A patch was then soldered in place but a small air hole remained during the cooking process. Another small drop of solder then closed the air hole. At this rate, only 60 cans per day could be manufactured.

In 1868, interior enamels for cans were developed, but double seam closures using a sealing compound were not available until 1888. Aluminum particles were first extracted from bauxite ore in 1825 at the high price of $545 per pound. When the development of better processes began in 1852, the prices steadily declined until the low price of $14 per pound in 1942. Although commercial foils entered the market in 1910, the first aluminum foil containers were designed in the early 1950s, while the aluminum can appeared in 1959.

After cans were invented and progressively improved, it was necessary to find a way to open them. Until 1866, a hammer and chisel was the only method. It was then that the keywind metal tear-strip was developed. Nine years later (1875), the can opener was invented. Further developments modernized the mechanism and added electricity, but the can opener has remained, for more than 100 years, the most efficient method of retrieving the contents. In the 1950s, the pop top/tear tab can lid appeared and now tear tapes that open and reseal are popular. Collapsible, soft metal tubes, today known as “flexible packaging,” were first used for artist’s paints in 1841. Toothpaste was invented in the 1890s and started to appear in collapsible metal tubes. But food products really did not make use of this packaging form until the 1960s. Later, aluminum was changed to plastic for such food items as sandwich pastes, cake icings and pudding toppings.

Plastics: Plastic is the youngest in comparison with other packaging materials. Although discovered in the 19th century, most plastics were reserved for military and wartime use. Styrene was first distilled from a balsam tree in 1831. But the early products were brittle and shattered easily. Germany refined the process in 1933, and by the 1950s foam was available worldwide. Insulation and cushioning materials as well as foam boxes, cups and meat trays for the food industry became popular.

Vinyl chloride, discovered in 1835, provided for the further development of rubber chemistry. For packaging, molded deodorant squeeze bottles were introduced in 1947, and in 1958, heat shrinkable films were developed from blending styrene with synthetic rubber. Today, some water and vegetable oil containers are made from vinyl chloride.

Another plastic was invented during the American Civil War. Due to a shortage of ivory, a U.S. manufacturer of billiard balls offered a $10,000 reward for an ivory substitute. A New York engineer, John Wesley Hyatt, with his brother Isaiah Smith Hyatt, experimented several years before creating the new material. Patented in 1870, “celluloid” could not be molded, but rather carved and shaped, just like ivory.

Cellulose acetate was first derived from wood pulp in 1900 and developed for photographic uses in 1909. Although DuPont manufactured cellophane in New York in 1924, it wasn't commercially used for packaging until the late 1950s and early 1960s. In the interim, polyethylene film wraps were reserved for the military. In 1933, films protected submarine telephone cables and later were important for World War II radar cables and drug tablet packaging.

Other cellophane and transparent films have been refined as outer wrappings that maintain their shape when folded. Originally clear, such films can now be made opaque, colored or embossed with patterns. The Polyethylene Terephthalate (PETE) container only became available during the last two decades with its use for beverages entering the market in 1977. By 1980, foods and other hot-fill products such as jams could also be packaged in PETE. Current packaging designs are beginning to incorporate recyclable and recycled plastics but the search for reuse functions continues.

Labels and Trademarks: One rather recent development in packaging is the labeling of the product with the company name and contents information. In the 1660s, imports into England often cheated the public and the phrase “let the buyer beware” became popular. Inferior quality and impure products were disguised and sold to uninformed customers. Honest merchants, unhappy with this deception, began to mark their wares with their identification to alert potential buyers.

Official trademarks were pioneered in 1866 by Smith Brothers for their cough drops marketed in large glass jars. This was a new idea-using the package to “brand” a product for the benefit of the consumer. In 1870, the first registered U.S. trademark was awarded to the Eagle-Arwill Chemical Paint Company. Today, there are nearly 750,000 registered trademarks in the United States alone. Labels now contain a great deal of information intended to protect and instruct the public.

17.6 SUMMARY:

The purpose of food packaging must continue to be maintaining the safety, wholesomeness, and quality of food. The impact of packaging waste on the environment can be minimized by prudently selecting materials, following guidelines given by government. Knowledgeable efforts made by industry, government, and consumers to understand the functional characteristics of packaging will prevent much of wastages. In the future maybe traditional packaging will be replaced by innovative food packaging techniques.

17.7 TECHNICAL TERMS:

Food Packaging, Safety Issues, Safety, Material Strength, Role Of Packaging, Product Information, Protection.

17.8 SELF ASSESSMENT QUESTIONS:

1) Define packaging?
2) Why do we need to package food? Give the scope of packaging.
3) Indicate the relevance of food packaging to developing countries?

17.9 REFERENCE BOOKS:

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LESSON-18

TYPES, PROPERTIES, ADVANTAGES & DISADVANTAGES OF PACKAGING MATERIALS

18.0. OBJECTIVES:

After studying this unit, you should be able to

- Characterize different types of packaging materials for foods;
- Explain properties of food packaging;
- Specify advantages, and disadvantages of food packaging

STRUCTURE:

18.1 INTRODUCTION

Packaging plays a prominent role in the protection, preservation, transportation, and marketing of food products. Whether in food industry, appropriate packaging materials are essential to ensure product safety, extend shelf life, and enhance consumer appeal. The choice of packaging material depends on several factors, including the nature of the product, quantity, environmental impact, cost, and regulatory requirements.

Packaging materials can be broadly classified into various types such as paper, plastic, glass, metal, and biodegradable alternatives etc. Each type has its own unique set of physical and chemical properties that influence its suitability for specific applications. For instance, while glass offers excellent barrier properties and inertness, it is fragile and heavier compared to plastic, which is lightweight and versatile but may raise environmental concerns.

This lesion explores the types of packaging materials commonly used across industries, examines their properties, and evaluates their advantages and disadvantages. A comprehensive understanding of these aspects is essential for selecting the most effective packaging solution that balances functionality, sustainability, and cost-efficiency.

18.2 TYPES OF FOOD PACKAGING

Food packaging serves several key functions: protecting food from contamination, extending shelf life, making transportation easier, and providing important product information. The choice of packaging depends on the food type, storage requirements, shelf life expectations, and marketing considerations. Below are the main types of food packaging (Fig 18.1):

18.2.1 PRIMARY PACKAGING

Primary packaging is the first layer of packaging that is in direct contact with the food product. It plays a vital role in preserving food quality, ensuring safety, hygiene, and extending shelf life by protecting against physical, chemical, and biological alterations. This type of packaging also creates the ideal headspace - the volume of air within the package—to maintain the product's freshness and prevent spoilage.

Also referred to as retail packaging or consumer units, primary packaging is the form that consumers directly handle, making it essential for marketing, branding, and regulatory labeling. It not only influences purchasing decisions through visual appeal but also conveys important information such as nutritional facts, expiration date, and usage instructions.

Functions of Primary Packaging:

- Acts as a barrier against moisture, air, light, microorganisms, and physical damage.
- Helps extend shelf life by minimizing exposure to spoilage agents.
- Holds the product in a manageable unit, preventing leakage or contamination.
- Designed for easy handling, opening, resealing, pouring, or serving.
- Provides vital product information: ingredients, nutrition, usage instructions, manufacturing/expiry dates, etc.
- Serves as a visual and promotional tool to attract customers.
- Includes safety features like seals or shrink bands to show if the product has been opened or altered.

Common Materials Used in Primary Packaging: Cardboard Cartons, Plastic Trays and Containers, Glass Bottles and Jars, Multi-Layered Structures (e.g., Tetra Pak), etc.

18.2.2 SECONDARY PACKAGING

Secondary packaging is the layer of packaging that groups multiple primary packages together into a single unit. It is primarily used for logistics, handling, and distribution, playing a vital role in the safe transportation of products from manufacturers to retailers. While it does not directly touch the food product, it ensures that the primary packages remain intact and undamaged during storage and transit.

Typically made from corrugated cardboard, secondary packaging is designed to provide strength, stability, and cushioning. It also allows for bulk handling, reducing the effort and cost involved in moving large quantities of product.

In addition to its protective and logistical functions, secondary packaging can sometimes serve marketing or display function, particularly in retail environments. It may be designed to open easily and function as a shelf-ready or display-ready package, making it convenient for store staff to stock and for customers to access products.

Functions of Secondary Packaging:

- Consolidates multiple primary units for easier transportation and storage
- Provides additional protection against physical damage
- Simplifies inventory management and shipping
- May serve as point-of-sale display in supermarkets or retail stores
- Common Materials Used in Secondary Packaging:
- Corrugated Cardboard Boxes: The most common material, valued for its strength, light weight, and recyclability
- Shrink Wraps and Plastic Films: Used to bundle products together (e.g., water bottles or canned drinks)
- Paperboard Sleeves or Wraps: Sometimes used to group items like chocolate bars or multipack snacks.

18.2.3 TERTIARY PACKAGING

Tertiary packaging is the outermost layer of packaging used during bulk handling, shipping, and warehouse storage. Its primary role is to protect and consolidate large quantities of primary and secondary packaged goods for safe and efficient transportation. This type of packaging is essential in logistics and supply chain operations, especially when moving products between production facilities, distribution centers, and retail locations.

Although it is not seen by consumers, tertiary packaging plays a critical role in maintaining the integrity and stability of products during long-distance shipping and extended storage.

Fig. 18.1: Types of food packaging

Functions of Tertiary Packaging:

- Shields multiple units from damage caused by impacts, vibration, or compression during transport and storage.
- Allows for the grouping of many items into a single, manageable unit.
- Supports stacking and space optimization in warehouses or during shipment.
- Streamlines the supply chain by enabling fast and organized distribution of goods.
- Secures goods during transport, reducing the risk of tampering, pilferage, or product loss.
- Stabilizes the load through wrapping or strapping techniques.
- Common Materials Used in Tertiary Packaging:
- Pallets: Flat structures (typically wood or plastic) used to support goods in a stable fashion.
- Shrink Wrap or Stretch Wrap: Plastic film tightly wrapped around pallets to hold secondary packages together.
- Corrugated Shipping Cases: Outer boxes or containers placed on pallets, made from strong cardboard to house multiple secondary packages.
- Strapping: Plastic or metal bands used to hold boxes or goods together on a pallet.

18.3 PROPERTIES OF FOOD PACKAGING

Food packaging must meet several essential **functional, physical, and chemical** properties to ensure the safety, quality, and longevity of food products. These properties determine how well the packaging can protect the food, preserve its freshness, and withstand various environmental and handling conditions (Table 18.1).

18.3.1 Physical Properties: Barrier Properties and Permeability

1. Barrier Properties: Barrier properties refer to a packaging material's capacity to block or resist the passage of external agents such as gases (oxygen, carbon dioxide), moisture, aromas, and light. These properties are crucial in ensuring the preservation of food quality, freshness, and safety (Fig 18.2 & 18.3).

Fig. 18.2a: Examples of Food Packaging Materials

- **Oxygen Barrier**: Prevents oxidation, which can lead to spoilage, discoloration, and nutrient loss.
- **Moisture Barrier**: Maintains the food's moisture content and prevents microbial growth or dehydration.
- **Light Barrier**: Shields light-sensitive foods from UV or visible light that can degrade flavors, nutrients, and colors.

Examples of materials with excellent barrier properties:

- **Glass** - Impermeable to gases and moisture; excellent light protection when tinted.
- **Metal (Aluminum, Tinplate)** - Total barrier to light, moisture, and gases.
- **EVOH (Ethylene Vinyl Alcohol)** - A high-performance plastic with exceptional gas barrier properties, often used in multilayer packaging.

2. Permeability: Permeability is the rate at which gases or moisture can pass through a packaging material. It is measured in terms of transmission rates such as:

- **Oxygen Transmission Rate (OTR)**
- **Water Vapor Transmission Rate (WVTR)**

- **Low permeability** is desirable for most food packaging, as it helps preserve product shelf life by minimizing exposure to air and humidity.
- **Controlled permeability** may be useful for packaging certain fresh produce that requires some gas exchange to stay fresh (e.g., fruits and vegetables).

Fig. 18.2b: Examples of Food Packaging Materials

18.3.2. Mechanical and Thermal Properties of Food Packaging Materials

1) **Mechanical Properties:** Mechanical properties define a packaging material's strength, durability, flexibility, and resistance to physical stress or deformation. These properties are vital for maintaining package integrity during handling, transportation, storage, and consumer use.

   - **Tensile Strength**: Measures the amount of force needed to stretch or break a material. High tensile strength is essential for durability, especially in films and flexible packaging.
   - **Impact Resistance**: The material's ability to withstand sudden shocks or drops without cracking or breaking.
   - **Tear and Puncture Resistance**: Important for flexible packaging (e.g., bags and pouches) to avoid accidental rupture.
   - **Flexibility and Elasticity**: Allows materials to bend or stretch without damage. Essential in wraps, foils, and films used for irregularly shaped products.
   - **Compression Resistance**: Particularly important for secondary and tertiary packaging used in stacking and transport.

Examples:

- **Corrugated cardboard**: Good compression resistance.
- **Plastic films**: Flexible but may vary in puncture resistance.
- **Glass**: Brittle with poor impact resistance.
- **Metal cans**: Strong and impact-resistant.

2) **Thermal Properties:** Thermal properties describe how packaging materials behave under various temperature conditions, including exposure to heat during processing (e.g., sterilization, pasteurization), storage (refrigeration or freezing), or consumption (microwaving or baking).

- **Thermal Conductivity**: The rate at which heat passes through a material. High thermal conductivity materials heat up or cool down quickly.
- **Heat Resistance**: The ability to retain shape and structure when exposed to high temperatures.
- **Low-Temperature Resistance**: The ability to maintain flexibility and strength without cracking when frozen.

Material Behavior:

- **Glass and Metal**:
  - High thermal conductivity.
  - Withstand high heat—ideal for **oven-safe** containers.
  - Suitable for heat-treated foods (e.g., retortable cans, glass jar for canning).
- **Plastics**:
  - Generally lower thermal conductivity.
  - Some plastics (e.g**.,** polypropylene, CPET) are designed to be microwave-safe or freezer-stable.
  - Others may deform, melt, or release harmful substances at high temperatures.

18.3.3 Chemical Properties of Food Packaging Materials

1. Chemical Resistance and Interactions: Chemical resistance refers to a packaging material's ability to remain stable and unaffected by chemical exposure—whether from the food product itself, environmental conditions, or external contaminants.

- **Inertness**: Chemically inert materials do not react with or alter the food product.
- **Migration**: Some packaging materials may release **additives, plasticizers, or residual monomers** into food, leading to **off-flavors, odors**, or **health risks**.
- **Absorption**: Packaging can sometimes absorb food components (like oils or flavors), compromising product quality.
- **Glass**:
  - Chemically inert.
  - Does not react with acids, alcohols, or other food substances.
  - Ideal for **sensitive or acidic foods** (e.g., pickles, sauces).

- **Metal (e.g., aluminum, tinplate)**:
    - Inert when coated with a **protective lacquer** or **polymer lining**.
    - Without coatings, may react with acidic foods, causing corrosion and metallic taste.
- **Plastics**:
    - Vary widely in chemical resistance depending on polymer type.
    - **PET** and **HDPE** are relatively resistant and commonly used for beverages and food storage.
    - **PVC**, **PS**, and **some multilayer films** may raise concerns due to **migration of additives** or degradation under heat or acidic conditions.

2. Recyclability and Sustainability: Modern packaging design considers not only performance but also environmental impact, emphasizing recyclability and sustainability.

- Defined as a material's capacity to be **reprocessed into new products** without significant degradation.
- **Glass**: Infinitely recyclable without quality loss.
- **Metals** (aluminum, steel): Highly recyclable, energy-efficient recovery.
- **Plastics**:
    - **PET, HDPE**: Widely recyclable.
    - **Multi-layered or laminated plastics**: Difficult to separate and recycle.
- **Paper/Paperboard**:
    - Recyclable, but fibers degrade with each cycle, limiting reuse.
    - Coated papers (e.g., with plastic or wax) may not be recyclable in standard systems.
    - Sustainability: Sustainable packaging reduces environmental footprint through:
- Use of **renewable or recycled materials**.
- **Lightweighting** to reduce material and energy use.
- Design for **reuse, recyclability**, or **compostability**.
- Minimizing **carbon emissions** during production and transportation.

Biodegradable and Compostable Packaging:

- Designed to **break down under specific conditions** (e.g., industrial composters).
- Made from **natural polymers** like starch, PLA (polylactic acid), or cellulose.
- Not all biodegradable materials are suitable for **home composting**.

Table 18.1: Different Properties of Food Packaging Materials

Material	Chemical Resistance	Recyclability	Sustainability Notes
Glass	Excellent	Yes (infinite cycles)	Heavy, energy-intensive to make
Metal	Excellent (with coating)	Yes	High recycling efficiency
PET, HDPE	Good (varies by type)	Yes	Widely accepted in recycling
PVC, PS	Variable (may leach)	Limited	Environmental concerns
Paperboard	Moderate	Yes (if uncoated)	Fibers degrade over time
Bioplastics	Moderate to good	Varies	Requires special facilities

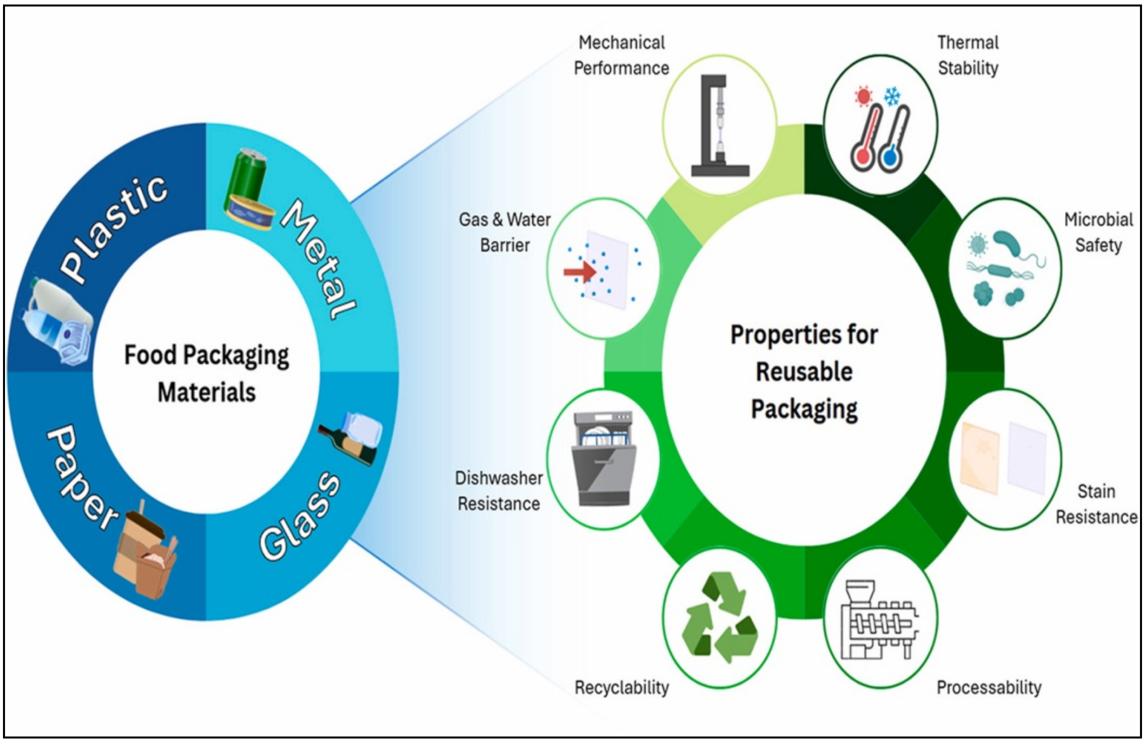

Fig. 18.3: Properties of Food Packaging

18.4 ADVANTAGES AND DISADVANTAGES OF FOOD PACKAGING

- Packaging has both negative and positive effects. However, information on these effects will help raise consumer awareness and help them choose packaging that is safe both personally and environmentally.
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- Packaging has both negative and positive effects. However, information on these effects will help raise consumer awareness and help them choose packaging that is safe both personally and environmentally (Table 18.2).

18.4.1 ADVANTAGES OF FOOD PACKAGING

Though people buy food all the time, most have never taken time to think about the food and its packaging. Some of the key benefits or advantages of food packaging are containing food, preserving and protecting food, transporting, as well as allowing effective communication and selling of the packaged food product.

Containing Food: A lot of Science encompasses the various packaging forms and the most effective ones for different food types. For instance, the chemical reactions that occur with powders, liquids, and solids differ from those of other compounds. This is the main reason why approvals for packaging are the strictest globally.

THE ADVANTAGES AND DISADVANTAGES OF FOOD PACKAGING

Packaging has both negative and positive effects. However, information on these effects will help raise consumer awareness and help them choose packaging that is safe both personally and environmentally.

Protecting Food: Products such as oils and beers are packaged with the sole purpose protecting their quality and integrity. Additionally, packaging keeps the product safe by keeping them free of foreign objects. Packaged foods are free of contamination. This contamination may be either naturally occurring or man-made.

Preserving Food: Food products should not only be kept safe, but their shelf life should also be extended. Packaging is an effective means of preserving food, as well as extending the shelf life of the food product.

Communication: Packaging is also an excellent way of communicating about the product inside effectively. A food package may contain ingredients. nutritional content, allergen information and even cooking instructions. It is therefore evident that food packaging is an excellent way of communicating to the consumer about the product contained in the package.

18.4.2 DISADVANTAGES OF FOOD PACKAGING

The amount of food packaging on an individual food product or other consumer item has increased. While packaging does improve safety, offer convenience and reduce theft, it also comes with a number of disadvantages. Packaging can be bulky, expensive and environmentally damaging over the course of its life cycle.

Cost: While packaging can do a lot to get customer attention, and may even add value to a product, it also adds to the cost of production and the eventual retail price. According to Know this, packaging can represent as much as 40 percent of the selling price of products in industries such as the cosmetic industry. New packaging can be expensive to develop, adding to the cost of products.

Landfill Impact: Packaging is responsible for significant portions of the waste stream. Some waste can be recycled, but many materials are not appropriate for recycling. Post-consumer recycled content is often usable only in specific contexts. For instance, many types of recycled plastic may not be used in food containers, even if the original plastic came from food containers. Much of the waste produced by packaging ends up in a landfill.

Table 18.2: Advantages and Disadvantages of Food Packaging

Advantages	Disadvantages
Protects food from contamination and damage	Generates **non-biodegradable waste** (especially plastics)
Extends shelf life by reducing spoilage	Uses **natural resources** and energy in production
Offers **convenience** for storage and transport	Can be **costly**, especially advanced or eco-packaging
Provides **labeling and branding** information	Risk of **chemical leaching** into food from some materials
Ensures **tamper-evidence and product safety**	Some packaging is **difficult to recycle**
Facilitates **bulk handling and distribution**	**Over packaging** creates unnecessary waste

18.5 SUMMARY:

Packaging materials play a vital role in preserving food quality, ensuring safety, and facilitating transportation and marketing. Based on their function, packaging can be categorized into primary, secondary, and tertiary types-each serving a distinct purpose from direct contact with food to bulk handling and distribution. The effectiveness of packaging is determined by its physical, mechanical, thermal, and chemical properties, such as barrier performance, strength, thermal resistance, and chemical stability. These characteristics help maintain food integrity and extend shelf life.

While food packaging offers several advantages, including protection, convenience, shelf life extension, and consumer information, it also presents challenges such as environmental pollution, recycling issues, cost, and potential health concerns due to material-food interactions. To balance functionality with sustainability, the development and adoption of eco-friendly, recyclable, and biodegradable materials are essential. A thoughtful approach to packaging can help reduce environmental impact while maintaining food quality and safety.

18.6 TECHNICAL TERMS:

Food packaging, food quality, safety, properties, protection, consumer information, health, environmental pollution.

18.7 SELF ASSESSMENT QUESTIONS:

1) Discuss the types of food packaging and describe their roles in the distribution process.
2) Explain the mechanical and thermal properties of packaging materials with suitable examples.
3) Describe the chemical interactions that can occur between packaging materials and food.
4) Evaluate the advantages and disadvantages of modern food packaging, focusing on environmental impacts.
5) How do packaging properties influence food quality, shelf life, and consumer safety?

18.8 REFERENCE BOOKS:

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2) Sanjay Mavinkere Rangappa, Jyotishkumar Parameswaranpillai, Senthil Muthu Kumar Thiagamani, Senthilkumar Krishnasamy, Suchart Siengchin. Food Packaging: Advanced Materials, Technologies, and Innovations, 2020.

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LESSON-19

TYPES OF PACKAGING MATERIAL AND THEIR TESTING: FORMS OF PACKAGING - BOX, BOTTLE, TETRA, POUCH, SHRINK, VACUUM, GAS, CAP, MAP, ASCEPTIC ETC.

19.0. OBJECTIVES:

After studying this unit, you should be able to

- The sampling plan of packaging materials for testing;
- Explain the requirement of conditioning for test specimens;
- Describe testing methods for different packaging materials; and

STRUCTURE:

19.1 INTRODUCTION

Packaging plays a vital role in the protection, preservation, transportation, and presentation of products. It is a critical component in ensuring product quality, safety, and shelf life, especially in industries such as food, pharmaceuticals, and consumer goods. With technological advancements and increased consumer awareness, the variety and complexity of packaging materials and forms have grown significantly.

Packaging is a fundamental aspect of product design and distribution, serving multiple essential functions-from safeguarding the product against physical damage, contamination, and environmental degradation, to enhancing its visual appeal and ensuring regulatory compliance. With the growing demand for extended shelf life, sustainability, product safety, and convenience, modern packaging has evolved into a sophisticated field involving a wide range of materials, technologies, and forms.

Packaging can be broadly categorized based on material type (such as paper, plastic, metal, glass, etc.) and packaging form (such as boxes, bottles, pouches, etc.). Each form and material is chosen carefully depending on the nature of the product, consumer convenience, cost-effectiveness, branding, logistics, and environmental concerns.

Moreover, packaging materials must undergo a series of tests to validate their strength, barrier properties, chemical compatibility, environmental resistance, and overall performance. These tests ensure that the packaging is fit for purpose and complies with national and international standards for safety and quality.

Early 19th century cans were produced from iron and steel that had been tin-plated. Early twentieth packaging innovations included transparent cellophane overwraps and panels on cartons, Bakelite caps on bottles, and better food safety. As new materials were created, such as aluminium and various kinds of polymers, they were used to packaging to enhance performance and utility. Used food packaging is put through quality control procedures to make sure it's safe for consumers and the environment.

19.2 SAMPLING PLAN

A sampling plan is required to draw the samples for testing from a large size of lot or batch. A batch is a set of particular type of packaging materials which can be regarded as homogeneous. A set of samples in the total number of individual samples taken from a batch of packaging materials e.g. paper, paperboard, and Corrugated Fiber board Box, roll of plastic films or laminates. And a specimen is a piece of particular type of packaging materials from an individual sample.

19.3 CONDITIONING OF TEST SPECIMENS

In the field of packaging technology and materials testing, conditioning of test specimens is a critical preliminary step that ensures the accuracy, reliability, and repeatability of test results. Before subjecting packaging materials or products to mechanical, physical, or chemical tests, they must be brought to a standardized environmental state. This process-known as conditioning-allows the material to reach equilibrium with a defined atmosphere in terms of temperature and relative humidity over a specified period.

Conditioning is especially important because most packaging materials-such as paper, paperboard, plastics, laminates, adhesives, and composites-are sensitive to environmental conditions. These materials can absorb or release moisture, expand or contract, and change their mechanical properties when exposed to different temperatures or humidity levels. Without proper conditioning, test results can be inconsistent, misleading, or not comparable across different laboratories or batches.

19.4 FORMS OF PACKAGING

Packaging plays a vital role in the food industry, acting as a protective barrier, a communication tool, and a vehicle for distribution. The form of packaging refers to the physical shape and structure in which food products are enclosed and presented to consumers. Each form is selected based on several key factors including the type of food (solid, liquid, perishable, dry, etc.), shelf life requirements, mode of distribution, convenience, and environmental concerns.

As the food industry continues to grow and diversify, the forms of packaging have evolved from simple wraps to sophisticated, multi-layered, and high-barrier solutions. These packaging forms not only protect the contents from contamination, spoilage, and mechanical damage, but also enhance shelf appeal, brand identity, and consumer convenience.

19.4.1 BOX PACKAGING

Box packaging is one of the most commonly used forms of packaging in the food industry. It provides a rigid or semi-rigid enclosure that protects food items during transportation, handling, and storage. Box packaging is typically made from paper-based materials and is widely valued for its low cost, recyclability, customizability, and eco-friendly nature.

Box packaging refers to a three-dimensional container, usually made from paperboard or corrugated cardboard, used to enclose and protect food products. It can serve as primary packaging (direct contact with food) or secondary packaging (grouping primary packages).

19.4.1.1 Common Materials Used in Box Packaging (Food Industry)

Box packaging in the food industry relies on a variety of materials depending on the type of food**,** storage conditions**,** strength required, and sustainability goals**.** Below are the most commonly used materials:

PAPERBOARD (CARTON BOARD)

Paperboard, also known as carton board, is a thick, paper-based material typically made from virgin or recycled pulp. It is stronger and more rigid than regular paper and is often used for primary packaging that comes in direct contact with food, or for secondary packaging to group products.

Paperboard is lightweight, printable, and foldable, making it highly adaptable for different food packaging needs.

Fig. 19.1: Paperboard Testing Equipment.

CORRUGATED FIBRE BOARD (CORRUGATED CARD BOARD)

Corrugated fibre board is a multi-layered paperboard material made of one or more fluted (wavy) inner sheets sandwiched between flat linerboards. This structure provides strength, cushioning, and rigidity, making it ideal for shipping and protective packaging of food items.

Common Uses in the Food Industry

Outer shipping boxes for primary food packages, Pizza boxes, Trays for fruits and vegetables, Bulk packaging for dry goods, Protective cartons for bottles, cans, and jars, Egg boxes (in molded form).

Fig. 19.2: Corrugated Fibre Board Testing Equipment

Kraft Paper Board

Kraft paperboard is a strong, durable paper-based material made using the Kraft process, where wood pulp is treated with chemicals to remove lignin, resulting in a high-strength, and unbleached brown paper. It is thicker and more rigid than standard Kraft paper, and is used extensively in packaging that prioritizes durability and sustainability.

Kraft paperboard is commonly brown or natural in color, although it can be bleached for a white appearance. It is valued for its toughness, tear resistance, and eco-friendly nature.

Common Uses in the Food Industry

Takeaway food boxes and trays, Paper bags for bakery items, Eco-friendly fast food containers, Wrapping for sandwiches and dry snacks, Outer sleeves for cups and trays, Ready-to-eat meal cartons.

Fig. 19.3: Kraft Paper Board Testing Equipment

COATED PAPER BOARD: Coated paperboard is a paper-based packaging material that has been treated with a layer of plastic (such as polyethylene), wax, or clay to enhance its barrier properties. The coating is applied to improve moisture, grease, and sometimes oxygen resistance, making it suitable for packaging food products that need extra protection from environmental elements.

Common Uses

Frozen food boxes (vegetables, ready meals), Ice cream cartons, Bakery boxes (cakes, pastries), Snack boxes, Greasy or oily food containers.

Fig. 19.4: Coated paperboard testing equipment

19.4.1.2. Bottle Packaging

Bottles are rigid, hollow containers with narrow necks, typically used to store liquid and semi-liquid food products. They are available in various materials, sizes, shapes, and closures and are chosen based on product compatibility, shelf life, safety, and consumer convenience.

Bottle packaging plays a critical role in preserving product quality, enabling branding, and ensuring hygienic delivery of consumables.

Glass Bottles

Glass is a rigid, transparent, and inert packaging material made primarily from silica (sand), soda ash, and limestone, melted at high temperatures. It is formed into bottles of various shapes and sizes, offering premium quality protection for food and beverages. Glass is valued for its non-reactive nature, making it ideal for sensitive products.

Common Food Uses: Beverages: Juices, milk, soft drinks, beer, wine, spirits, Sauces and condiments: Ketchup, pickles, vinegar, chutneys, Dairy products: Yogurt drinks, flavoured milk, Gourmet and organic foods: Honey, jams, syrups, olives.

Fig. 19.6: Bottle Packaging Testing Equipment.

PET (Polyethylene Terephthalate) Bottles

PET is a thermoplastic polymer resin belonging to the polyester family. It is lightweight, transparent, tough, and shatter-resistant, making it ideal for a wide range of food and beverage packaging applications. It is one of the most commonly used plastics globally due to its cost-efficiency, safety, and recyclability.

Common Food Uses

Packaged drinking water and carbonated soft drinks, Fruit juices, flavored beverages, energy drinks, Edible oils and salad dressings, Condiments like vinegar or soy sauce, Ready-to-drink milkshakes, lassi, and tea, Honey and syrups.

HDPE (High-Density Polyethylene)

HDPE is a strong, opaque thermoplastic polymer made from petroleum. It has a high strength-to-density ratio, making it ideal for packaging food and beverages. HDPE is durable, chemical-resistant, and lightweight, and is widely used for packaging products that require protection from moisture, light, and contamination.

Common Food Applications:

- Milk and dairy bottles, Juices and drinking yogurts,Cooking oils
- Liquid sweeteners, Sauces and condiments, Bulk food containers (e.g., 5L or 20L drums for oil).

PP (Polypropylene) in Food Bottle Packaging

Polypropylene (PP) is a semi-rigid, lightweight, and versatile thermoplastic polymer. It is highly resistant to heat, chemicals, and moisture, making it an excellent material for food contact applications. PP is widely used in bottles, caps, closures, jars, and microwaveable containers.

Common Food Applications:

Syrups, honey, and sauces bottles, Dairy products (yogurt cups, drinkable, urds), Microwaveable food containers, Spice jars and dry food containers, Caps and closures for PET and HDPE bottles, Reusable food containers and lunch boxes**.**

Aluminum (Metal Bottles):

Aluminum bottles are lightweight, rigid containers made from aluminum metal, often with an internal food-safe lining or coating. Known for their barrier protection, recyclability, and premium feel, aluminum bottles are increasingly used in beverages and specialty liquid food products**.** They offer excellent protection from light, oxygen, moisture, and contaminants**.**

Common Food & Beverage Applications:

Carbonated drinks (energy drinks, beer, soda), Still beverages (water, juices, cold brew coffee), Alcoholic beverages (wine, cocktails), Liquid concentrates and syrups, Ready-to-drink (RTD) beverages, Gourmet oils and specialty vinegars.

19.4.1.3. Tetra Packaging Materials

Tetra packaging (e.g., Tetra Pak cartons) is a multi-layer composite structure, designed for long shelf life, safety, and sustainability.

A. Major Materials Used

1) **Paperboard (~70–75%)**
   - Function: Provides stiffness, shape, and strength.
   - Features: Printable surface for branding/labeling.
   - Testing Focus: Strength, stiffness, recyclability.
2) **Polyethylene (PE, ~20–25%)**
   - **Function:** Serves as a moisture barrier, heat-sealable layer, and adhesive between materials.
   - **Layers:**
     - Outer PE (protection from moisture).
     - Inner PE (food contact layer & sealing).
     - Intermediate PE (binding to aluminum & paper).
     - Testing Focus: Seal integrity, migration safety, thickness uniformity.
3) **Aluminum Foil (~5%)**
   - **Function:** Provides an excellent barrier to oxygen, light, and microorganisms → enables aseptic packaging and long shelf life.
   - **Testing Focus:** Pinholes, thickness, OTR/WVTR (gas and moisture transmission).

4) **Optional Additives**

- Printing inks and coatings (for design & brand visibility).
- Biodegradable polymers (in some eco-friendly Tetra Pak versions).

2. Testing of Tetra Packaging:

Tetra packaging must undergo strict quality control and safety evaluations.

A. Materia Testing

B. **Paperboard Testing**

- *Grammage Tester* → measures basis weight (gsm).
- *Thickness Gauge* → measures caliper of board.
- *Bursting Strength Tester* → resistance to rupture.
- *Stiffness Tester* → flexural rigidity.
- *Cobb Sizing Tester* → water absorption capacity.
- **Polyethylene Testing**
  - *Hot Tack Tester* → seal strength of PE at different temperatures.
  - *Tensile Tester* → elongation and tensile properties.
  - *Migration Test Chambers* → ensures no harmful migration into food.
- **Aluminum Foil Testing**
  - *Pin Hole Detector* → checks foil continuity.
  - *Thickness Gauge (Micrometer)* → uniformity of foil layer.
  - *Gas Permeability Tester* → OTR (Oxygen Transmission Rate).
  - *Moisture Analyzer* → WVTR (Water Vapor Transmission Rate).

C. Package Integrity Tests

- **Leak Test Equipment**
  - Vacuum leak detector (checks for micro-leaks in seals).
- **Compression Tester**
  - Measures stacking strength of cartons.
- **Drop Tester**
  - Simulates dropping from specified heights.
- **Burst Tester**
  - Measures ability to withstand internal pressure.
- **Peel/Seal Strength Tester**
  - Evaluates heat-sealed joint strength.

D. Barrier Property Tests

- **WVTR Tester (Mocon or similar)**
  - o Measures moisture permeability.
- **OTR Tester**
  - o Evaluates oxygen barrier properties.
- **Light Transmission Tester**
  - o Checks UV and visible light barrier of aluminum layer.

E. Environmental Testing

- **Recycling Equipment**
  - o Fiber recovery testers (how well paperboard can be recycled).
- **Decomposition Studies**
  - o Eco-testing for biodegradable/compostable variants.

19.4.1.4. Pouch Packaging

Pouch packaging has become highly popular in the food industry due to its flexibility, lightweight nature, ease of use, and extended shelf life**.** Pouches are often made using multi-layer laminate structures to provide the necessary barrier properties and mechanical strength required to protect food products.

Polyethylene (PE):

Polyethylene (PE) is one of the most widely used plastics in the food packaging industry due to its flexibility, toughness, moisture resistance, and sealability. It is often used as the inner layer in multilayer pouch laminates and is FDA-approved for direct food contact.

Applications in Food Pouch Packaging:

Snacks and chips pouches, Frozen food bags, Cereal liners, Condiment and sauce pouches, Liquid refill pouches, Baby food pouches (as inner layers).

Aluminum Foil in Food Pouch Packaging:

Aluminum foil is a thin sheet of pure aluminum used as a barrier layer in multilayer flexible packaging structures. It is known for its exceptional barrier properties against light, oxygen, moisture, and contaminants**,** making it ideal for preserving food freshness, flavor, and shelf life.

In food pouches, it is typically laminated with plastic films such as PET, PE, or nylon to create retort, vacuum, or aseptic packaging**.**

Common Food Applications:

Retort pouches for ready-to-eat meals, Coffee, tea, and spice pouches, Shelf-stable baby food pouches, Pharmaceutical nutritional supplements, Dehydrated foods and soup mixes, Military or camping rations.

Nylon (Polyamide – PA)

Nylon, also known as polyamide (PA)**,** is a strong, flexible, and transparent thermoplastic used primarily in multi-layer flexible pouches**.** It provides excellent mechanical strength, puncture resistance**,** and moderate barrier properties. Due to its toughness and durability, it is a preferred material for vacuum and retort pouches**.**

Common Food Applications:

Vacuum-sealed meat, cheese, and fish, Boil-in-bag meals, Retort pouches for ready-to-eat foods, Processed meats and deli products, Frozen food packaging, Seafood packaging.

EVOH (Ethylene Vinyl Alcohol)

EVOH is a high-performance barrier polymer used in multilayer food packaging films, especially in pouches**,** trays, and bottles**.** It is known for its exceptional oxygen barrier properties**,** which help in extending shelf life and maintaining the aroma, color, and nutritional quality of packaged food.

EVOH is almost always sandwiched between protective layers like PE, PP, PET, or Nylon, since it is sensitive to moisture.

Common Applications in Food Pouches:

Ready-to-eat meals (retort pouches), Vacuum-sealed meats and sausages, Baby foods and purees, Dairy products (yogurt, cheese packaging), Processed fruits and vegetables, Ketchup, sauces, and condiments.

19.4.1.5. Shrink Packaging

- Definition**:** Packaging process where a polymer film shrinks tightly over the product when heat is applied.
- **Materials Used:**
  - Polyolefin (POF)
  - Polyvinyl chloride (PVC)
  - Polyethylene (PE)
- **Process:**
  1) Product is wrapped in shrink film.
  2) Film is exposed to heat (heat tunnel or hot air gun).
  3) Film shrinks and conforms tightly around product.

- **Applications:**
  - Food trays, bottles, cans, multipacks, fresh produce.

19.4.1.5.1. Shrink Packaging – Testing

- Visual Inspection → To check uniform shrinking, wrinkles, or holes.
- Seal Integrity Test → Heat-sealed seams are tested for strength and leakage.
  - *Equipment:* Heat seal tester, peel strength tester.
- Thickness/Film Strength Test → Ensure shrink film resists puncture and tearing.
  - *Equipment:* Tensile tester, puncture resistance tester.
- Shrink Force Test → Measures shrink tightness on product.
  - *Equipment:* Shrink force analyzer.
- Drop Test → Packaged items dropped from standard height to test protection.

Fig. 19.7: Shrink Packaging Testing Equipment

19.4.1.6. Vacuum Packaging

- **Definition:** Packaging method where air is removed from the package before sealing.
- **Materials Used:**
  - High barrier films (PA/PE, PET/PE laminates).
- **Process:**

1) Product placed in pouch.
2) Air is evacuated using a vacuum pump.
3) Package is heat-sealed.

- **Applications:**
  - Meat, cheese, coffee, nuts, dry powders.

Vacuum Packaging - Testing

- Vacuum Level Test → Confirms correct vacuum pressure achieved.
  - *Equipment:* Vacuum gauge, digital pressure sensors.
- Leak Detection Test → Detects micro-leaks in the sealed pack.
  - *Equipment:* Water immersion method (bubble test), vacuum leak detector.
- Seal Strength Test → Ensures seals can withstand vacuum stress.
  - *Equipment:* Peel strength tester, tensile tester.
- Residual Oxygen Measurement → Ensures minimal oxygen remains inside.
  - *Equipment:* Oxygen analyzer.
- Compression/Drop Test → Checks product resistance to handling and storage.

19.4.1.6. Gas Packaging

- **Definition:** Packaging technique where the headspace is filled with a specific gas or gas mixture instead of air.
- **Common Gases Used:**
  - Carbon dioxide (CO_2) → inhibits microbial growth.
  - Nitrogen (N_2) → inert, prevents oxidation, acts as filler.
  - Oxygen (O_2) → maintains red color in fresh meat, supports respiration in fresh produce.
- **Applications:**
  - Snack foods, bakery items, meat, coffee, fresh produce.
  - Gas Packaging – Testing (also applies to CAP and MAP, but with some differences)
- **Headspace Gas Analysis** → Checks concentration of CO_2, N_2, O_2 inside pack.
  - *Equipment:* Gas analyzer (non-destructive needle probes).
- **Leak Detection** → Ensures gases don't escape over time.
  - *Equipment:* CO_2 leak detector, bubble test, pressure decay tester.
- **Seal Strength Test** → Ensures package integrity.
- **Oxygen Transmission Rate (OTR) Test** → Confirms packaging material barrier properties.
  - *Equipment:* Gas permeability tester.
- **Microbiological Testing** → Evaluates effect of gas on microbial growth.

19.4.1.7. Controlled Atmosphere Packaging (CAP)

- **Definition:** Packaging where the atmosphere inside the package is continuously monitored and adjusted to maintain preset levels of gases.
- **Process:**
  - o Constant regulation of O_2, CO_2, N_2 using gas sensors and control systems.
- **Applications:**
  - o Large-scale storage of apples, pears, bananas, and other fruits.

Controlled Atmosphere Packaging (CAP) – Testing

Since CAP involves continuous gas control in storage chambers, testing is more about environment monitoring:

- Gas Concentration Monitoring (continuous) → O_2, CO_2, N_2 levels controlled.
  - o *Equipment:* Infrared gas analyzers, O_2 sensors, CO_2 sensors.
- Temperature & Humidity Monitoring → Essential for fruits/vegetables.
  - o *Equipment:* Digital hygrometers, thermocouples.
- Respiration Rate Testing of Produce → Checks CO_2/O_2 exchange rates.
  - o *Equipment:* Closed chamber respiration analyzer.

19.4.1.8. Modified Atmosphere Packaging (MAP)

- **Definition:** Packaging technique where the atmosphere is modified at the time of sealing but not actively controlled afterward.
- **Types:**
  - o Gas flushing.
  - o Vacuum + gas flushing.
- **Applications:**
  - o Meat, poultry, bakery, ready-to-eat meals, salads, fish.

Modified Atmosphere Packaging (MAP) – Testing

(Similar to Gas Packaging, but gases are not continuously controlled)

- Headspace Gas Analysis → Confirms initial gas composition after sealing.
- Residual Oxygen Test → Ensures oxygen reduced to desired level.
  - o *Equipment:* Oxygen analyzer.
- Gas Retention Test → Checks if gases remain stable over shelf life.
  - o *Equipment:* Leak detection system, CO_2 analyzer.
- Barrier Property Tests → WVTR (moisture barrier), OTR (oxygen barrier).
- Seal Integrity Tests → Vacuum chamber test, dye penetration test.

19.4.1.9. Aseptic Packaging

- **Definition:** Packaging system where both the product and the packaging material are sterilized separately**,** then filled and sealed in a sterile environment.
- **Materials Used:**
  - o Multi-layer cartons (Paperboard + PE + Aluminum foil).
  - o Plastic bottles, cups, or pouches.
- **Sterilization Methods:**
  - o Product → UHT (Ultra-High Temperature) treatment.
  - o Packaging → H_2O_2, heat, or UV sterilization.
- **Applications:**
  - o Milk, fruit juices, soups, sauces, liquid eggs.

Aseptic Packaging - Testing

- Sterility Test of Product → Confirms product remains free from microbes.
  - o *Equipment:* Incubators, culture media, microbial assay kits.
- Sterility of Packaging Material → Checks if sterilization (H_2O_2, UV, heat) is effective.
- Seal Integrity & Leak Test → Ensures sterile barrier not broken.
  - o *Equipment:* Vacuum leak detector, bubble test.
- Accelerated Shelf-Life Testing → Simulates storage to verify safety and quality.
  - o *Equipment:* Climatic chambers.
- Migration Tests → Ensures packaging does not release harmful chemicals.
  - o *Equipment:* GC-MS, HPLC (chemical analysis).
- Barrier Testing → OTR, WVTR tests on multilayer cartons.

19.5 SUMMARY

Packaging plays a vital role in protecting products, extending shelf life, and ensuring safe distribution from manufacturer to consumer. Different forms of packaging-primary, secondary, tertiary, and quaternary-serve distinct purposes, ranging from direct product protection to bulk transportation and global logistics.

Equally important is the testing of packaging, which evaluates mechanical strength, barrier properties, seal integrity, and environmental performance. Testing ensures that packages can withstand handling, storage, and transport stresses, while also maintaining product quality and safety. For food and pharmaceuticals, additional tests such as migration, sterility, and shelf-life studies are essential to meet regulatory and consumer safety standards.

19.6 TECHNICAL TERMS:

Packaging, Aseptic Packaging, Modified Atmosphere Packaging etc.

19.7 SELF ASSESSMENT QUESTIONS:

1) Differentiate between MAP and CAP?
2) Why is testing important in packaging?
3) Explain the different forms of packaging and their functions in detail?

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LESSON-20

WVTR, GTR, BURSTING STRENGTH, TENSILE STRENGTH, TEARING STRENGTH, DROP TEST, PUNCTURE TEST, IMPACT TEST

20.0. OBJECTIVES:

After studying this unit, you should be able to

- To measure how much moisture vapor passes through a packaging material over time;
- To determine how much gas (O_2, CO_2, N_2) permeates through the packaging film;
- To determine the maximum pulling (tensile) force a material can resist before breaking; and
- To measure a package or material's ability to absorb sudden shocks or impacts.

STRUCTURE:

20.1 INTRODUCTION

Packaging plays a vital role in the protection, preservation, and presentation of food products. To ensure that packaging materials maintain food quality and safety during handling, transportation, and storage, various mechanical and barrier property tests are conducted. These tests evaluate the strength, durability, and barrier efficiency of packaging materials under different conditions.

The major tests used to assess packaging performance include WVTR, GTR, Bursting Strength, Tensile Strength, Tearing Strength, Drop Test, Puncture Test, and Impact Test.

20.2 WATER VAPOUR TRANSMISSION RATE (WVTR)

One of the prime functions of the packaging materials is to act as barrier to gases and vapours. Many hygroscopic foods have to be protected from oxygenated water vapour pick up. The measurement of permeability is therefore very important. Method of Test: The water vapour permeability may be measured by means of high vacuum techniques, although there are simple gravimetric methods available which determine Water Vapour Transmission Rate (WVTR) much easily. In this method the value of water vapour permeability is determined by the increase in weight of a dish filled with desiccant (Eg. anhydrous calcium chloride), covered with the test specimen and sealed with molten wax or vacuum grease.

Fig. 20.1: Water Vapour Transmission Rate

The sealed dish is placed in a humidity cabinet maintained at 38 ± 1°C and R.H. 90 ± 2 %. The WVTR is computed by the following formula:

$$\text{WVTR} = \frac{G \times 24 \;\; g/m^2/24 \text{ hrs}}{A \times T}$$

Where;

G = weight gained in gm

T = time during which gain in weight is observed

A = area of the sample exposed in m^2

Typical WVTR Values of Common Packaging Materials

Aluminum foil: ~0 g/m^2/day (excellent barrier)

Glass & Metal: ~ Og/m2/day (impermeable)

Polyethylene (PE): 0.1-0.5 g/m²/day

Polypropylene (pp): 0.5-2g/m²/day

Paper: 50-100 g/m²/day (poor barrier, unless coated).

20.3 GAS TRANSMISSION RATE (GTR)

Gas Transmission Rate (GTR) is the amount of gas that permeates through a given area of packaging film per unit time at a specific temperature, humidity, and pressure difference.

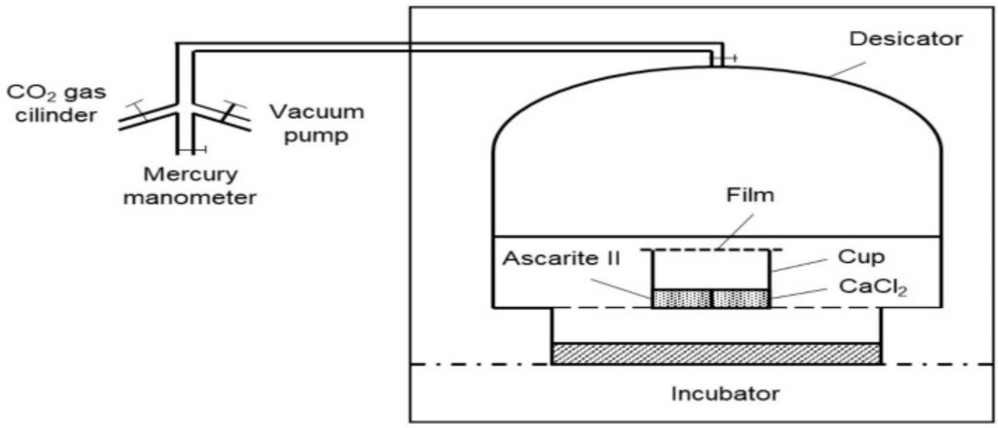

Fig. 20.2: Gas Transmission Rate

Unit of Measurement

The GTR is usually expressed as:cm^3/m^2/day/atm(or) sometimes as:cc/m^2/24h

Importance in Food Packaging

GTR determines how well a packaging material can protect the food from gases that cause spoilage or quality loss.

Gas	Why It Matters	Example
Oxygen (O_2)	Causes oxidation, rancidity, color and flavour changes	Chips, nuts, dairy
Carbon Dioxide (CO_2)	Controls microbial growth, used in MAP	Fresh meat, bakery
Water Vapor (H_2O)	Affects texture, weight, and crispness	Biscuits, cereals
Nitrogen (N_2)	Used as an inert gas to displace O_2	Snack foods, beverages

Factors Affecting GTR

1) **Type of material –** plastics, aluminum, paper have different permeability.

   e.g., Metallized films have low GTR (better barrier).

2) **Temperature –** higher temperature increases GTR.
3) **Humidity –** affects hydrophilic polymers (like Nylon, EVOH).
4) **Film thickness –** thicker films have lower GTR.
5) **Pressure difference –** higher pressure gradient increases gas flow.

Testing Methods

GTR is measured using instruments like:

- **MOCON Gas Permeation Analyzer**
- **ASTM Standards:**
  - **ASTM D1434 -** Standard Test Method for Gas Permeability of Plastic Film
  - **ASTM F1927** - Standard Test Method for Determination of Oxygen Gas Transmission Rate (O_2GTR)

Principle:

A test film separates two chambers - one with the test gas and the other under vacuum or with carrier gas. The amount of gas permeating through the film is measured over time.

Typical GTR Values (for O_2 at 23°C, 0% RH)

Material	GTR (cc/m²·day·atm)	Barrier Property
LDPE	2000–8000	Poor
PET	50–100	Moderate
EVOH	0.01–1	Excellent
Aluminum foil	~0	Perfect barrier

Applications

- **MAP (Modified Atmosphere Packaging) –** choosing films with the right GTR helps maintain desired gas balance inside packs.
- **Aseptic & vacuum packaging –** low GTR materials prevent oxidation and spoilage.
- **Snack & beverage packaging –** ensures long shelf life and product stability.

20.4 BURSTING TEST

Bursting Strength: **(IS 1009-1966 Part I)**

Bursting strength of paper and paperboard is determined in order to assess both strength and toughness of the material. It is essentially the ability of the sample to absorb energy. Method of Test: The sample is fixed between clamps. The area exposed is 1.2 in2. The sample is subjected to steadily increasing pressure hydraulically exerted on a rubber diaphragm beneath the sample until it ruptures. The maximum pressure required to rupture the sample is automatically recorded by a pressure gauge. This test is of importance in routine quality check of packaging material during manufacture.

Eg: Corrugated Boxes.

Fig. 20.3: Burst Test

A flexible pack's burst strength is measured by inflating it with air at a certain pace until it bursts, which reveals how strong its seal is. Along with the burst pressure value, the failure's place and type (material or seal) are also noted. The test is used to determine how likely it is that a pack would break when subjected to pressure discrepancy, such as those that could occur during retorting or air shipment. Because the forces during pressurisation are distributed more evenly over the perimeter of the pack when it is placed between supporting plates, the weakest location of the seals is more likely to be found.

- ASTM F 1140 (Method A& B1 but not B2)
- ASTM F 2095 (Method A& B)
- ASTM F 2054

20.5 TENSILE AND T-PEEL TESTING

A mechanical test called a tensile strength test is done on packing materials to find out how much force can be applied to it before it breaks or ruptures. It is essentially a "pulling" test that assesses the durability of paper, board, and plastics. The material will behave elastically up to a point before rupturing. The test is adaptable and can be used to gauge a material's tensile strength, elongation, tearing resistance, as well as the amount of force needed to break a seal. Similar to tensile testing, T-peel testing measures the mechanical strength of a material by applying a load to a portion of a packing seal to see how long it can withstand before breaking.

Fig. 20.4: Tensile and T-peel Testing

20.6 TEAR STRENGTH OR TEARING RESISTANCE: (ASTM, D 689-79 Part 20)

This test is performed on papers and it gives an indication towards the strength of the paper. It is helpful in making selection of papers based on material for packaging purposes. The tear strength requirements may be high or low according to end use of the packaging material. This test measures the energy absorbed by the test sample in propagating a tear that has already been initiated by cutting a small nick in the test piece.

Method of Test: The Elmendorf tearing tester has two grips set side by side with only a small separation. One grip is stationary and is mounted on an upright on the instrument base. The second grip is movable and is mounted on a pendulum. The pendulum is mounted on a frictionless bearing and swings on a shaft. The sample of 50 x 62 mm size is clamped in the two grips and a cut is made using a sharp knife fixed on the tester. When the pendulum is released, it swings down on pre-cut sample. This indicates the residual energy lost in tearing and expressed in mN (milli Newton).

Tear Growth Test on Plastic Films

The test mimics how packing foils will behave when the product is opened. The initial tearing strength should be about equal to the remaining tearing strength while opening a plastic bag. There is a risk that the packaging will spontaneously break apart fully and the stuff will pour out if the maximum power during first tearing is too great. Since the tensile strength and rip resistance of stretched foils are both very direction dependent, adjusting the appropriate behavior is difficult. ASTM D1004-13 Tear Resistance (Graves Tear) of Plastic Film or Sheeting is the recommended test method.

Fig. 20.5: Tear Growth Test on Plastic Films

20.7 DROP TEST

The Drop Test is a mechanical performance test used to evaluate how well a packaged product can withstand impact or shock during handling, transportation, and storage.

It simulates accidental drops that might occur in real-world conditions to ensure that the package protects the product inside without significant damage.

Purpose of Drop Test

To determine:

- The strength and durability of the package.
- The shock resistance of the packaging material and closure.
- Whether the contents remain intact after drops.
- Compliance with transport safety standards.

Standards Used: Common international standards for conducting drop tests include:

- **ASTM D5276** – Standard Test Method for Drop Test of Loaded Containers by Free Fall
- **ISO 2248** – Packaging – Complete, Filled Transport Packages – Vertical Impact Test by Dropping
- **ISTA Series 1A, 2A** – Performance Tests for Packaged Products

Test Equipment

- **Drop Tester Machine** (Free-fall or Guided type)
  - A platform holds the package and releases it from a specific height.
  - The height is adjustable according to weight and package type.
- **Measuring Devices** for height, impact, and deformation.

Fig. 20.6: Drop Test

Test Procedure

1) **Prepare the Test Sample:**A filled and sealed package is used to simulate real shipping conditions.

2) **Select Drop Height:** Based on package weight or transport handling conditions.

Weight of Package	Drop Height (Approx.)
Up to 10 kg	100–120 cm
10–25 kg	80–90 cm
25–50 kg	60–70 cm
Above 50 kg	45–60 cm

1) Drop orientations tested:

- **Flat drops:** on top, bottom, and sides.
- **Edge drops:** on edges most likely to receive impacts.
- **Corner drops:** on the weakest corner (worst-case scenario).

2) Observe and record results:

- Cracks, leaks, seal failures, or deformation.
- Damage to both packaging and product.

Evaluation Criteria: After the test, the package is evaluated for:

- **Structural integrity:** No tearing, splitting, or crushing.
- **Seal performance:** No leakage or product loss.
- **Product protection:** Contents remain undamaged.
- **Label and print legibility** remain intact.

Applications in Food Packaging: Used for:

- **Glass bottles** (beverages, sauces)
- **Plastic containers** (PET bottles, HDPE jars)
- **Cartons and Tetra packs**
- **Flexible pouches** (liquid foods, snacks)
- **Corrugated boxes** (bulk transport)

Example:

- A Tetra Pak for milk may be dropped from 1.2 m to ensure no leakage or corner rupture.
- A PET bottle drop test ensures it won't crack when dropped during handling.

20.8 PUNCTURE TEST

The Puncture Test is a mechanical test used to measure a packaging material's resistance to piercing or puncturing by a sharp object. It helps assess the durability, toughness, and protective strength of food packaging materials-especially films, laminates, and flexible pouches.

Purpose of the Puncture Test

To evaluate:

- How well the packaging can resist sharp impacts during handling, transportation, or storage.
- The mechanical strength and toughness of the material.
- Whether the package can prevent leakage or contamination if accidentally impacted.

Fig. 20.7: Puncture Test

Food packages can be damaged by:

- Sharp corners of other packages,
- Forklifts or machinery,
- Accidental impacts, or
- Sharp ingredients (like bones, chips, or nuts inside the pack).

A **high puncture resistance** ensures:

- No holes or leaks occur,
- Shelf life and food safety are maintained.

Applicable Standards: Common international standards include:

- **ASTM D5748 –** Standard Test Method for Protrusion Puncture Resistance of Stretch Wrap Film
- **ASTM D781 –** Standard Test for Puncture and Stiffness of Paperboard
- **ISO 7765-1 / 7765-2 –** Plastics Film – Determination of Puncture Resistance

Types of Puncture Tests

1) **Static Puncture Test**

- Measures the force required to puncture the film slowly using a pointed probe.
- Used for film materials like LDPE, PET, or laminated structures.

2) Dynamic Puncture Test

- Measures the energy absorbed when a weight or dart hits the film at high speed.
- Simulates real-world impacts during handling or transport.
- Commonly called the Dart Impact Test (ASTM D1709).

Test Equipment

- **Puncture tester** with:
  - A fixed sample holder (to clamp the film).
  - A metal probe or dart of defined shape and size.
  - Force or energy sensor to measure resistance.

Test Procedure (Static Puncture Example)

1) **Sample Preparation:** Cut a piece of the film and mount it tightly in the test frame.
2) **Probe Selection:** Use a standard puncture probe (hemispherical or conical tip).
3) **Testing:** The probe is pressed into the film at a constant speed until puncture occurs.
4) **Recording:**
   - **Maximum force (N)** needed to puncture.
   - **Deformation (mm)** before rupture.
5) **Result:** Puncture Resistance = Maximum Force (N) or Energy (J)

Factors Affecting Puncture Resistance

- **Material type** (LDPE < Nylon < PET < EVOH)
- **Film thickness** (thicker = stronger)
- **Temperature** (colder films = more brittle)
- **Moisture content** (can soften some materials)
- **Lamination quality**

Applications in Food Packaging

Used for testing:

- Snack pouches, Frozen food bags, Vacuum-sealed meat packs, Aseptic cartons, Metalized film laminates.

20.9 IMPACT TEST:

Bottles that are used again and again, often meets certain amount of impact in their daily use. In order to ensure that such bottles do not fail, this test is performed. In this test a steel ball of 400gm is dropped from a height of 10 cm on the bottle held rigidly. In case of milk bottles the ball is dropped thrice on the same spot on the bottle and the bottle should not freak or crack. In the pendulum test the steel ball swings and strikes at the bottle held rigidly.

Types of Impact Tests

1) **Free-Fall Impact Test (Drop Impact)**
   - Simulates a package falling onto a hard surface.

- Used for rigid containers, bottles, and filled packs.
- Measured by the height or energy at which damage occurs.

2) Pendulum Impact Test (Charpy/Izod Type)

- Measures the **energy absorbed** by a specimen when struck by a swinging pendulum.
- Common for plastic films, bottle materials, or packaging sheets.

3) Dart Impact Test (ASTM D1709)

- Specifically used for flexible films.
- A dart-shaped weight is dropped from a fixed height to determine the energy required to cause failure (rupture).

Fig. 20.8: Pendulum Impact Testing

20.10. SUMMARY:

Packaging tests such as WVTR, GTR, Bursting Strength, Tensile Strength, Tearing Strength, Drop Test, Puncture Test, and Impact Test are essential for evaluating the quality, strength, and protective ability of food packaging materials. These tests ensure that packaging provides adequate barrier properties, mechanical strength, and durability to maintain the safety and shelf life of food products.

WVTR and GTR determine the barrier efficiency of packaging materials against moisture and gases, helping to preserve freshness and prevent spoilage. Bursting, Tensile, and Tearing Strength Tests assess the mechanical integrity and toughness of the material, ensuring it can withstand stresses during filling and sealing. Meanwhile, Drop, Puncture, and Impact Tests evaluate the resistance to shocks, piercing, and handling damage, ensuring that the package remains intact during transportation and storage.

Overall, these tests collectively help in selecting appropriate, reliable, and safe packaging materials that protect food products, maintain quality, and enhance consumer satisfaction.

20.11. TECHNICAL TERMS:

Permeability, Diffusion, Relative Humidity (WVTR, GTR), Stress, Strain, Modulus, Tear Force (Tensile, Tearing), Impact Energy, Drop Height, Puncture Energy (Drop, Puncture, Impact).

20.12. SELF ASSESSMENT QUESTIONS:

1) Define WVTR and explain its significance in food packaging
2) Name three gases commonly tested in GTR measurements and their impact on food quality.
3) What is bursting strength and which types of packaging is it mainly used for?
4) How does tear strength relate to consumer convenience and product protection?

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