

Study Guide

**POST GRADUATE DIPLOMA IN
PUBLIC HEALTH AND NUTRITION**

BASICS OF FOOD SCIENCE

Course Code: EDHNS-6014



Department of Nutritional Sciences & Environmental Design

Faculty of Sciences

ALLAMA IQBAL OPEN UNIVERSITY

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Units : 1-9



**Department of Nutritional Sciences and Environmental Design
Faculty of Sciences
ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD**

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FOREWORD

It is with great pleasure that the Department of Nutritional Sciences and Environmental Design, Faculty of Sciences, is offering PGD Public Health and Nutrition (PHN). The curriculum integrates the foundational principles of public health with cutting-edge insights into nutrition science, equipping students with the knowledge and skills necessary to address global and local health issues.

Public Health focuses on disease prevention and health on a broader scale, providing a comprehensive understanding of the social, economic, and environmental factors that shape health and well-being. Nutrition focuses on food science and its impact on health, particularly as diet-related illnesses rise in developing countries and food systems face increasing strain due to uncontrolled population growth. Understanding this field is essential for promoting healthier lives and communities.

Allama Iqbal Open University is dedicated to promoting an educational environment where creativity and responsibility go hand in hand. We believe that the next generation of professionals will play a fundamental role in shaping a sustainable future.

This study guide on the course “basics of food science” is structured to facilitate critical thinking, evidence-based analysis, and effective problem-solving, which are essential competencies for today’s health professionals.

I encourage you to approach this guide not only as a source of academic knowledge but also as a tool for fostering your passion for public service. Your work in public health and nutrition has the potential to make a significant impact on individual lives, communities, and entire populations.

I wish you success in your studies and hope that this guide will be a valuable companion on your educational journey, preparing you to meet the demands of a rapidly evolving field and contribute meaningfully to improving global health outcomes.

Best Wishes,

**Vice-Chancellor
Prof. Dr. Nasir Mehmood**

PREFACE

The Postgraduate Diploma in Public Health and Nutrition has been carefully designed to address the growing demand for skilled professionals who can tackle complex health and nutrition challenges in our society. As the world evolves, the importance of public health and nutrition in promoting well-being, preventing diseases, and ensuring sustainable health outcomes has become more critical than ever.

In an era of unprecedented global health challenges, including pandemics, malnutrition, and the rising burden of non-communicable diseases, this diploma equips students with the tools, knowledge, and skills necessary to lead positive health transformations in diverse settings. The curriculum integrates the latest scientific research, practical applications, and evidence-based strategies, ensuring that students are well-prepared to contribute meaningfully to the health sector, both locally and globally.

This study guide is designed to support you through each step of your journey. It outlines the key concepts, learning objectives, recommended readings, and assessment strategies for each unit. Whether your goal is to advance in your current role or to embark on a new career path in public health or nutrition, this guide will serve as a valuable resource throughout your academic experience.

I encourage you to approach this course with curiosity, critical thinking, and a commitment to applying your knowledge to real-world challenges. The faculty and I are dedicated to providing you with a supportive and enriching learning environment. Together, we will explore the vital intersections of health, nutrition, and public policy to build healthier communities.

I wish you success in your studies and look forward to seeing the impact you will make in the field of public health and nutrition.

Sincerely,

**Dean, Faculty of Sciences
Allama Iqbal Open University**

MESSAGE FROM CHAIRMAN

Dear Students,

Welcome to the Department of Nutritional Sciences and Environmental Design's diploma program in Public Health and Nutrition. I am pleased to announce the development of a comprehensive study guide focused on a basic understanding of the Basics of Food sciences.

This guide aims to equip all students with the necessary knowledge of the Basics of Food Science. You will understand basic constituents present in different foods along with their chemistry in detail, with a clear understanding of their functions in the human body. Understanding these concepts is essential not only for your health but also for the health of your family and the broader community.

I encourage all students to actively engage with the study guide and utilize its resources to enhance their understanding of macronutrients. Together, we can create awareness about healthy eating choices and healthful behaviour for better nutrition through the life cycle.

Thank you for your attention to this important matter. If you have any questions or suggestions, please don't hesitate to reach out to the program coordinator.

Stay Safe, Stay Vigilant!

Best Wishes,

Dr. Zaheer Ahmed
Chairman, Department of Nutritional
Sciences and Environmental Design

ACKNOWLEDGEMENT

All praises to **Allah**, who gave me the strength to complete this project. The development of this comprehensive study guide on "Basics of Food Sciences" has been a collaborative effort, drawing upon the expertise and support of numerous individuals. It gives me immense pleasure to express my profound gratitude and reverence to the Vice Chancellor of Allama Iqbal Open University, **Prof. Dr. Nasir Mehmood** for guiding, facilitating, and supporting the preparation of the course. We extend our heartfelt gratitude to all those who have contributed to the creation of this resource.

I would like to express my sincere appreciation to **Prof. Dr. Hajra Ahmad**, Dean, Faculty of Sciences, for her support and encouragement. Thanks to **Dr. Zaheer Ahmed**, Chairman, Department of Nutritional Sciences and Environmental Design, for his sustenance and trust. All the faculty members, especially **Dr. Asma Afreen**, Assistant Professor, Department of Nutritional Sciences and Environmental Design, and **Ms. Khadija Amjad**, an expert in Community Health and Nutrition, provided valuable insights and guidance throughout this study guide's planning and development stages. Your expertise and dedication have been instrumental in ensuring the content's quality and relevance.

I also acknowledge the contributions of the design and editorial team, production, and printing team who worked diligently to ensure the clarity, coherence, and accessibility of the content presented in this study guide. Your dedication and attention to detail have been essential in bringing this resource to fruition.

Lastly, we extend our deepest appreciation to the post-graduate students who will use this study guide as a tool for learning and professional development. It is our sincere hope that it will serve as a valuable resource in your studies and practice of public health and nutrition in your daily life.

Thank you to everyone who has contributed to the creation of this study guide. Your collaboration and support have been invaluable in making this project a reality.

Course Coordinator

Course Team

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Course Outline

Basics of Food Science

Level: Post Graduate

Credit Hours: 3(3+0)

Introduction to the course

The course will provide students with an understanding of the basic application of scientific principles to understand the nature and behaviour of food components. It will help you to analyze the impact of processing and preservation methods on food quality and safety, evaluate food safety risks and implement appropriate control measures. Once they understand the basics, they can understand the nutritional aspects of food and their health implications.

UNIT-1: Introduction to Food Science

- 1.1 Food Science as a Discipline
- 1.2 Basic Constituents of Food
- 1.3 Food as a Source of Energy
- 1.4 Food and Its Functions

UNIT-2: Carbohydrates in Food

- 2.1 Monosaccharide
- 2.2 Disaccharides
- 2.3 Some Properties of Sugars
- 2.4 Oligosaccharides
- 2.5 Polysaccharides

Unit 3: Proteins in Food

- 3.1 Amino Acids
- 3.2 Protein Structure and Conformation: Reactions and Properties of Proteins
- 3.3 Enzymes

UNIT-4: Fat and Oil Products

- 4.1 Structure and Composition of Fats
- 4.2 Properties of Fats and Oils
- 4.3 Composition of Dietary Fats and Oils
- 4.4 Deterioration of Fats
- 4.5 Shortening and Shortening Power of Various Fats and Oils
- 4.6 Frying

UNIT-5: Water

- 5.1 Chemistry of Water
- 5.2 Specific Heat and Latent Heat of Water
- 5.3 Water as a Dispersing Medium
- 5.4 Water Activity

5.5 Role of Water in Food Preservation and Shelf Life of Food

UNIT 6: Meat, Poultry, Fish, and Dried Beans

- 6.1 Characteristics of Meat
- 6.2 Muscle Contraction in Live Animals
- 6.3 Poultry
- 6.4 Fish
- 6.5 Dried Beans and Peas (Legumes)
- 6.6 Meat Alternatives

UNIT 7: Milk and Milk Products

- 7.1 Composition of Milk
- 7.2 Sanitation and Grading of Milk
- 7.3 Flavour of Milk
- 7.4 Milk Processing
- 7.5 Types of Milk
- 7.6 Cooking Applications
- 7.7 Milk Substitutes and Imitation Milk Products

UNIT 8: Vegetables and Fruits

- 8.1 Structure and Composition of Cell Tissue
- 8.2 Pigments and Effects of Additional Substances
- 8.3 Harvesting and Postharvest Changes
- 8.4 Enzymatic Oxidative Browning
- 8.5 Fruits: Unique Preparation and Cooking Principles
- 8.6 Organically Grown Fruits and Vegetables
- 8.7 Labelling of Vegetables and Fruits

UNIT 9: Food Emulsions and Foams

- 9.1 Emulsions
- 9.2 Natural Emulsifiers
- 9.3 Synthetic Emulsifiers and Surfactants
- 9.4 Foams, Foam stability, foam formation
- 9.5 Foaming agents
- 9.6 Effect of added Ingredients on foam stability

Recommended Books:

1. Vickie A. Vaclavik & Elizabeth W. Christian (2008) Essentials of Food Science. 3rd Edition.
2. Devendra Kumar Bhatt and Priyanka Tomar (2006) An Introduction to Food Science and Technology & Quality Management.
3. Food Sciences and Its Application Course Code-867, AIOU Compiled Material.

INTRODUCTION

With this course, you will gain a thorough understanding of the methods and concepts that underpin food safety, processing, preservation, and production. Food science is a dynamic and diverse profession that works to make sure the food we eat is healthy and safe. In addition to producing more food with fewer resources, and adapting to changing consumer preferences and nutritional demands, the food business is facing several obstacles as the world's population continues to rise. The information and abilities you will gain from this course will enable you to tackle these issues and support advancements in the food industry. Unit one tells about food science as an interdisciplinary field involving the application of scientific principles to create and maintain a wholesome food supply and learning about the major components of food, including carbohydrates, proteins, fats, water, vitamins, and minerals. Unit two is based on studying carbohydrates and investigating the physical and chemical properties of sugars like solubility and sweetness. Unit three covers the proteins and their dietary importance along with the complex structures and folding patterns of proteins. Unit four is about understanding the chemical structure of fats and oils and exploring dietary fats composition and their nutritional implications. The fifth unit is about the thermal properties of water the importance of water activity and its significance in food preservation and safety. The Sixth unit helps to understand the composition, structure, and nutritional value of meat and meat alternatives and biochemical processes involved in muscle contraction and how they affect meat quality post-slaughter. Unit seven comprised of constituents of milk, different types of milk and various methods of milk processing. It tells about the standards for milk sanitation and grading to ensure safety and quality and the factors affecting the flavour of milk, including feed, processing, and storage conditions. Unit eight is about the cellular structure and composition of fruits and vegetables and their nutritional implications and how they are affected by cooking and additives. Unit nine is based on the nature of emulsions, their types, and their importance in food products. It explores the formation and stability of foams in food products and naturally occurring and synthetic emulsifiers and surfactants in food processing and their functional properties.

LEARNING OUTCOMES:

This course would focus on providing students with:

- A foundational understanding of the essential principles and concepts in food composition, nutrition, processing, and safety and the impact of food science on health and society
- Recognition of how chemistry, biology, nutrition, and engineering principles integrate to study food and the roles and functions of carbohydrates, proteins, fats, vitamins, minerals, and water in food.
- Understanding of basic food processing techniques such as pasteurization, homogenization, fermentation, and their impact on food quality and safety and application of these scientific principles to real-world food problems.

UNIT -1

INTRODUCTION TO FOOD SCIENCE

Written by:

Dr. Zaheer Ahmed
Ms. Khadija Amjad

Reviewed by:

Dr. Asma Afreen

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INTRODUCTION

Food science is an interdisciplinary study that utilizes ideas from basic sciences and engineering to comprehend foods' physical, chemical, and biological properties and the processes involved in their production. Food technology applies the information derived from food science to choose, protect, handle, package, and distribute food in a manner that guarantees its safety, nutritional value, and overall quality of eating. Food science extends diverse fields, from examining fundamental food characteristics to creating groundbreaking food items and technologies. Furthermore, food scientists utilize this information to tackle food production, safety, nutrition, and sustainability difficulties.

LEARNING OBJECTIVES

After studying this unit, you will be able to:

- ✓ To understand the scope and significance of food science.
- ✓ To identify the interdisciplinary connections within food science.
- ✓ To describe the roles and functions of macronutrients and micronutrients in food.

1.1 FOOD SCIENCE AS A DISCIPLINE

Food science is an interdisciplinary study that utilizes ideas from basic sciences and engineering to comprehend foods' physical, chemical, and biological properties and the processes involved in their production. Food technology applies the information derived from food science to choose, protect, handle, package, and distribute food in a manner that guarantees its safety, nutritional value, and overall quality of eating. Food science extends diverse fields, from examining fundamental food characteristics to creating groundbreaking food items and technologies. Furthermore, food scientists utilize this information to tackle food production, safety, nutrition, and sustainability difficulties.

Food science primarily focuses on examining the characteristics of food substances and how they interact with various preparation techniques. This entails analyzing variables such as agricultural methodologies, soil makeup, climatic conditions, and genetic attributes, all of which impact the quality and attributes of food constituents. For instance, the quantity of precipitation, soil composition, and harvesting techniques can significantly influence the taste, consistency, and nutritional value of fruits and vegetables.

Food science includes several specialized fields, such as food microbiology, food engineering, food chemistry, and sensory science. Food microbiologists analyze the microorganisms found in food and investigate their impact on the safety and quality of the meal. Food engineers specialize in transforming unprocessed agricultural materials into final food items using various processing techniques, whereas food chemists study the chemical makeup of foods and analyze how their qualities are altered during processing. In addition, sensory scientists examine the impact of sensory attributes such as taste, scent, texture, and appearance on consumer preferences.

As the food industry progressed and grew more intricate, the necessity for a more extensive comprehension of food science became evident. Food science guarantees the food supply's safety, quality, and nutritional content. Professionals in this field work in several areas to tackle food production, processing, and distribution difficulties.

1.2 BASIC CONSTITUENTS OF FOOD

Understanding the constituents of foods and their properties is fundamental to food science. While advanced students with knowledge in organic chemistry, physical chemistry, and biochemistry can grasp the molecular interactions between food constituents. Foods primarily consist of biochemical derived from living sources,

such as plants and animals. The major constituents in foods include carbohydrates, proteins, fats, and their derivatives. Additionally, foods contain inorganic minerals and organic substances in smaller proportions, including vitamins, enzymes, emulsifiers, acids, antioxidants, pigments, and flavours. Water, a vital constituent, is crucial in determining foods' structure, texture, taste, colour, and nutritional value.

The arrangement of these components within foods contributes to their unique characteristics. For instance, despite having similar water content, whole milk and fresh apples exhibit different physical states due to the organization of their components.

Appearance includes characteristics such as dimensions, form, hue, and arrangement, which indicate the state of being recently produced, fully matured, and of high quality. Texture, in the context of food, pertains to the tactile perceptions encountered during consumption, such as the qualities of being crisp, chewy, or creamy. Alterations in texture over time might serve as an indication of variations in quality, such as the presence of staleness or freezer burn.

Flavour, which encompasses taste and fragrance, is a highly subjective component of food quality. The taste buds detect the fundamental tastes of sweetness, saltiness, sourness, bitterness, and umami, whereas the olfactory system detects odors. Food's aroma is vital in evaluating its quality, frequently indicating freshness or deterioration. Food flavour is affected by multiple elements, such as sugars, acids, salts, and bitter chemicals.

1.2.1 Carbohydrates

Carbohydrates, originating from the term "hydrates of carbon," are organic molecules with a fundamental $C_x(H_2O)_y$ structure. These compounds present in many foods include sugars, dextrin, starches, cellulose, hemicelluloses, pectin, and some gums. At a chemical level, carbohydrates are composed of carbon, hydrogen, and oxygen atoms.

1.2.1.1. *Simple sugars:*

Simple carbohydrates, also called sugars, encompass glucose, a simple sugar composed of six carbon atoms. Glucose and other simple sugars assume ring structures, with variations in the positioning of oxygen and hydrogen atoms. These differences affect characteristics such as solubility, sweetness, and the likelihood

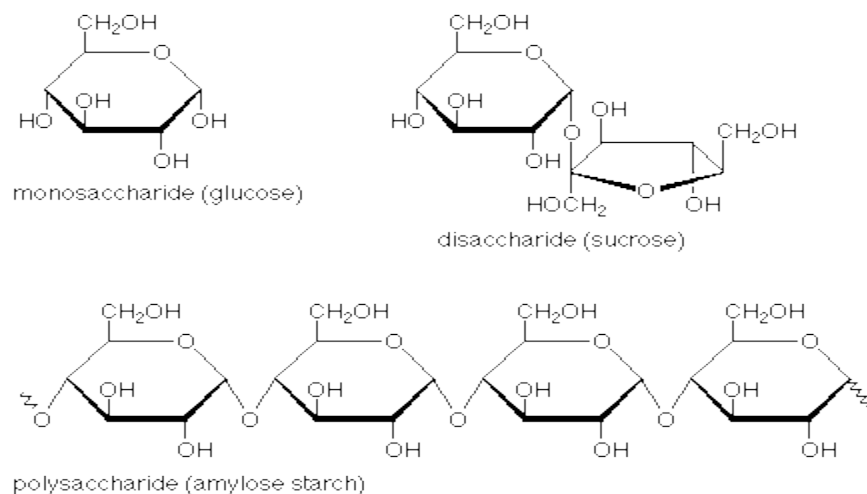
of being fermented by microorganisms.

Disaccharides:

Disaccharides, created by joining two sugar molecules and releasing a water molecule, consist of maltose, sucrose, and lactose. These demonstrate differences in characteristics like as solubility and taste.

Polysaccharides:

Polysaccharides are complex carbohydrates made up of several sugar units connected. Examples include amylose, which is found in plant starches, and cellulose. Complex carbohydrates are synthesized from simple sugars and their derivatives. Hydrolysis or enzymatic digestion processes can break them down into smaller components, such as monosaccharides. The functional groups present in sugars, such as hydroxyl groups and aldehyde or ketone groups, significantly impact their chemical characteristics. Reducing sugars, which contain unbound aldehyde or ketone groups, can interact with other components of food, influencing characteristics such as colour, flavour, and other attributes. Long-chain sugar polymers can cross-link, forming fibres, films, or gel-like networks. These materials are commonly used in food packaging applications.



1.2.1.2. Some Properties of Sugars:

Sweetness: Glucose, fructose, maltose, sucrose, and lactose are primarily valued for sweetness, although the degree varies.

Solubility: These sugars readily dissolve in water, forming syrups, and can crystallize upon water evaporation (e.g., sucrose recovery from sugar cane juice).

Energy Source: Sugars supply energy, serving as vital sources of calories in the diet.

Fermentation: They are easily fermented by microorganisms, a process utilized in various food and beverage productions.

Preservative Qualities: Sugars in high concentrations can inhibit microbial growth, acting as natural preservatives.

Changes: Upon heating, sugars can darken or caramelize, contributing to the flavour and colour of cooked foods.

Browning Reaction: Some sugars combine with proteins, resulting in the browning reaction, influencing the colour and flavour of cooked foods.

Texture and Mouthfeel: Sugars provide body and mouthfeel solutions, enhancing sensory attributes alongside sweetness.

1.2.1.3. Some Properties of Starches:

Not Sweet: Starches lack sweetness, which distinguishes them from sugars.

Solubility: Generally insoluble in cold water, starches form pastes and gels in hot water, contributing to various food textures.

Energy Source: Starches serve as an energy reserve in plants and provide dietary energy for humans.

Granule Structure: Starch granules, characteristic of seeds and tubers, undergo swelling and gelatinization upon heating in water, influencing viscosity and gel formation.

Thickening and Gelation: Starch pastes thicken foods, while starch gels, modifiable by sugar or acid, are used in desserts and culinary applications.

Modification: Techniques like enzymatic or chemical breakdown, cross-linking, and derivatization expand starch functionality, enhancing its use as a food ingredient.

1.2.1.4. Some Properties of Celluloses and Hemicelluloses:

Structural Role: Abundant in plants, celluloses and hemicelluloses provide structural support.

Resistance to Breakdown: Relatively resistant to breakdown, they remain insoluble in water and undigested by humans.

Dietary Fiber: Crucial as dietary fibre, it promotes digestive health and regularity.

Fibre Structure: Cellulose chains may form fibers, affecting food texture and resilience, while fibre-rich foods like celery contain cellulose.

Conversion to Glucose: Certain enzymes and microorganisms can break down cellulose and hemicellulose into glucose, offering nutritional benefits.

1.2.2 Proteins

All life forms require proteins formed by joining amino acids into lengthy chains. The primary components of these amino acids are nitrogen, oxygen, hydrogen, and carbon, while some also contain sulfur and other elements. Proteins have a variety of functions in animals. They can build anatomical structures like cartilage, skin, and muscle or be important components of hormones, enzymes, antibodies, and bodily fluids like blood, milk, and egg whites.

1.2.2.1. Chemical Structure

Amino acids are the building blocks of proteins. They may form peptide bonds with other amino acids because they have amino (-NH₂) and carboxyl (-COOH) groups linked to the same carbon atom. This mechanism creates peptides and proteins by joining amino acids into chains.

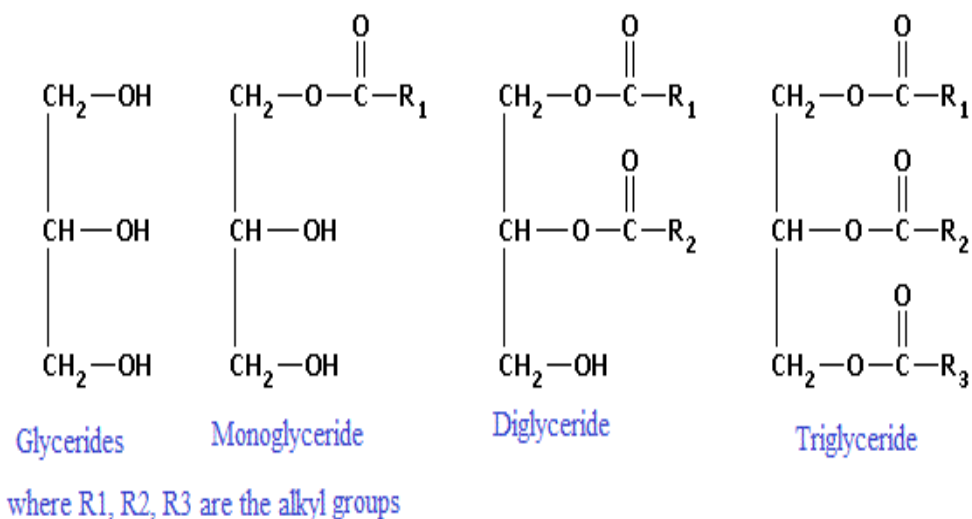
The 20 primary amino acids are categorized as either essential or non-essential depending on whether humans can produce them or if they must be received through diet. Of these, eight are considered essential. Since the body can make the remaining amino acids from other substances, they are called non-essential amino acids.

1.2.2.2. Protein Breakdown and Food Processing

In food processing, proteins are selected based on various functional characteristics, including dispersibility, solubility, viscosity, emulsification, foam stability, fibre production, and nutritional value. Proteins can be broken down into intermediates with various sizes and characteristics using acids, alkalis, and enzymes. While excessive breakdown can result in undesired changes like meat putrefaction, controlled breakdown, such as cheese ripening, enriches flavour and texture.

1.2.3 Lipids

Fats and oils, unlike carbohydrates and proteins, are not polymers but rather hydrophobic molecules with a smooth and oily texture that do not dissolve in water. They primarily function as a fuel source, containing around double the calories as an equivalent dry weight of protein or carbohydrate. In addition, fats transport fat-soluble vitamins (A, D, E, and K), sterols (such as cholesterol in animal fats and ergosterol in vegetable fats), and natural lipid emulsifiers like phospholipids. The composition of fat molecules involves the combination of glycerol with three fatty acids, resulting in the formation of triglycerides. The length and saturation of fatty acids impact fats' physical characteristics and nutritional significance. Saturated fatty acids undergo complete hydrogenation, whereas unsaturated fatty acids contain double bonds and exhibit varying levels of unsaturation.



1.2.3.1. Functional Characteristics of Lipids

- The melting values of fats differ depending on their fatty acid makeup. Fats containing longer and saturated fatty acids tend to have higher melting points, resulting in harder fats.
- Hydrogenation is a process that fully saturates fatty acids with hydrogen, transforming liquid oils into solid fats.
- Upon heating, fats undergo a progressive softening process and can cause browning on food surfaces.

- Fats possess smoke, flash, and fire points that are significant in commercial frying.
- Rancidity can arise from the oxidation of fatty acids by oxygen or enzymatic hydrolysis.
- Fats can create emulsions when combined with water and air, essential in producing different food items.
- They serve as lubricants, reducing agents, and flavour enhancers in foods.
- In small quantities, fats promote a feeling of fullness and increase the attractiveness of food.

1.2.4. Other food constituents

Although carbohydrates, proteins, and fats are commonly recognized as the primary components of food due to their high abundance, there are additional groupings of molecules that have important functions, even though they are present in smaller amounts in diets.

1.2.4.1. Natural Emulsifiers

Emulsifiers are compounds that maintain the dispersion of fat globules in water or water droplets in fat. Emulsifiers are essential for preventing the separation of water and oil layers in foods such as mayonnaise. Lecithin, present in egg yolk, is an important natural emulsifier. Lecithin, which is structurally analogous to fats but contains phosphoric acid, stabilizes emulsions by possessing a hydrophilic end that is attracted to water and a hydrophobic end that is attracted to fats. This configuration allows them to create a barrier around oil droplets, inhibiting their coalescence. Lecithin has a crucial role in maintaining the stability of emulsions in culinary products such as mayonnaise, margarine, and salad dressings.

1.2.4.2. Novel Components

Attempts have been undertaken to create substitutes for fat, sugar, and other constituents of food to decrease calorie content or enhance taste. These analogues imitate the functional characteristics of native components while decreasing the number of calories. For example, proteins from eggs or milk can be transformed into tiny spheres to substitute a portion or the entirety of the fat in ice cream, decreasing its calorie count. **Aspartame**, derived from amino acids, is an artificial sweetener significantly sweeter than sucrose, enabling its use in smaller quantities and reducing calorie intake.

1.2.4.3. Organic acids

Fruits have natural acids that provide a sour taste and help prevent the growth of

germs, therefore delaying spoiling. The process of fermenting foods with bacteria results in the production of acids, which improves the taste and extends the shelf life of the food. Organic acids have an impact on the texture and colour of food, as well as preventing bacterial deterioration, therefore ensuring its safety.

1.2.4.4. Oxidants and Antioxidants

The presence of oxygen in the air has a negative impact on fats, oils, and specific taste components, resulting in the development of rancidity and the deterioration of nutrients. Antioxidants such as vitamins C and E, lecithin, and synthetic compounds inhibit oxidation, maintaining food quality.

1.2.4.5. Enzymes

Enzymes are organic catalysts that facilitate metabolic reactions in food. They impact the process of ripening, the taste, the colour, and the nutritional characteristics. Enzymes are eradicated through heat processing, which results in the prolongation of food's shelf life. Commercial enzyme preparations alter the texture, taste, and other favorable alterations in foods.

1.2.4.6. Pigments and Colors

The colour of food is derived from the natural pigments found in plants and animals, the process of caramelizing sugars, and the chemical reactions between sugars and proteins. Food preparation frequently involves the deliberate use of natural or synthetic pigments for colouring purposes.

1.2.4.7. Flavors

The flavour of food is intricate and ever-changing, shaped by more than 800 chemical components found in certain foods. A product's flavour can be altered during handling, processing, and storage. Regional and cultural tastes play a significant role in determining whether these modifications are accepted.

1.2.5. Vitamins and Minerals

Vitamins and minerals in food are crucial for maintaining good health. However, how foods are formulated and processed can influence their nutritional content.

1.2.6. Water

Water is an essential life substance composed of hydrogen and oxygen molecules. Food's water content significantly impacts its texture, preservation ability, and

treatment methods. Regulating the moisture level is crucial in avoiding molding, hard crusts, or clumping and improving water quality in the food production industry.

1.3 FOOD AND ITS FUNCTIONS

Carbohydrates, proteins, and lipids have multiple interrelated functions in metabolism.

1.3.1. Carbohydrates:

Carbohydrates play crucial roles in both biological systems and food. They are generated during photosynthesis in plants, serving as nature's means of storing energy derived from sunlight. In addition, carbohydrates can function as structural elements (such as cellulose), energy stores (such as starch in plants and glycogen in animals), and vital components of nucleic acids and vitamins. Carbohydrates can undergo oxidation, which releases energy. They can also be fermented by bacteria, producing chemicals such as carbon dioxide, alcohol, and organic acids.

- Carbohydrates are a cost-effective source of calories and offer easily accessible energy for bodily functions. However, the body can also obtain energy and carbon from proteins and fats. Carbohydrates are necessary for effectively using fats by supplying an organic acid to oxidize lipids fully into carbon dioxide and water. Inadequate fat oxidation can result in ketosis, a condition characterized by the accumulation of ketone bodies in the bloodstream.
- In addition, carbs possess a protein-sparing impact. When there is a lack of carbs, the body releases fats and proteins through oxidation to provide energy. When no carbohydrates are available, the body uses protein oxidation to meet energy needs. However, this process depletes the protein stores necessary for bodily tissues, enzymes, and other nitrogen compounds. Nevertheless, in the presence of carbs, the body prefers utilizing them as an energy source, hence conserving proteins. Fats also exhibit a comparable protein-sparing impact.
- Carbohydrates such as cellulose and hemicellulose are vital in promoting gut health by providing fibre and bulk. Additionally, they have an impact on the composition of the gut bacteria. Microorganisms in the intestine utilize slowly fermentable carbohydrates, such as starch and lactose, as a source of nutrition. This process contributes to the production of several B-complex vitamins. Nevertheless, an excessive intake of lactose can result in diarrhoea for certain individuals. In addition, lactose ingestion has been linked to higher calcium retention in youngsters.

1.3.2. Proteins:

Proteins act as fundamental components for bodily tissues and other crucial compounds, supplying vital amino acids that the body cannot produce. Proteins have varying nutritional value depending on their makeup of amino acids.

- Amino acids (AAs) in humans serve other physiological activities beyond protein production. These functions encompass the regulation of gene expression, involvement in cell signalling pathways, regulation of food intake, chemical sensing, assistance in nutrient digestion and absorption, contribution to neurological development, facilitation of energy metabolism, promotion of antioxidative and anti-inflammatory processes, and osmolarity, and overall maintenance of homeostasis and well-being.
- Proteins constitute many immune system components, such as antibodies, cytokines, and immune cells. Adequate protein consumption enhances immune function and bolsters the body's ability to combat infections and illnesses.
- Enzymes, which are proteins, aid in several biochemical processes in the body such as digestion, metabolism, and detoxification. Sufficient protein consumption is necessary for the optimal operation of enzymes, which is crucial for overall well-being and vigour.
- Incorporating sufficient protein into one's diet can aid in weight management by stimulating sensations of fullness and satiety. Protein-rich meals aid in regulating blood sugar levels by slowing down the absorption of carbs and minimizing the increase in blood glucose levels after a meal. This is especially advantageous for persons who have diabetes or insulin resistance.
- Proteins have a crucial role in preserving bone health and avoiding the development of osteoporosis. Collagen, the predominant protein in the body, offers structural reinforcement to bones, while additional proteins aid in the absorption and utilization of calcium.
- Proteins facilitate wound healing. They play a crucial role in restoring and growing tissues such as the skin, muscles, and internal organs. Adequate protein consumption enhances the body's capacity to mend wounds and recuperate from injuries or surgical procedures.

1.3.3. Fats:

Fats provide energy and important fatty acids such as linoleic acid, which the body cannot produce and must be acquired through diet. Insufficient levels of linoleic acid might hinder the process of growth and lead to the development of skin diseases. Vitamins A, D, E, and K are linked to the lipid components of meals.

Excessive consumption of dietary fat leads to its accumulation in adipose tissue, which can contribute to obesity.

- Phospholipids arrange themselves into double layers in cell membranes, creating a sturdy barrier that divides the cell's interior from the outside environment. The fluidity of these membranes is affected by the fatty acid makeup of the phospholipids, where unsaturated fatty acids enhance fluidity, and saturated fatty acids reduce it.
- Phospholipids play a role in the packing and transporting of lipids in the bloodstream. They create a single layer on the surface of lipoprotein particles, such as chylomicrons and lipoproteins, which help to maintain their stability and ability to dissolve in the bloodstream.
- Mono- and diglycerides are chemical compounds that are formed after the breakdown of triacylglycerols. They are commonly used in processed foods as emulsifiers to stabilize oil-in-water emulsions.
- Cholesterol is a crucial constituent of cell membranes and has a significant impact on the fluidity of the membranes. It inserts itself into phospholipid bilayers, altering their fluidity and stiffness.
- Cholesterol acts as a precursor molecule for the production of steroid hormones (such as estrogen and testosterone), vitamin D, adrenal steroids (such as hydrocortisone and aldosterone), and bile acids.
- Phytosterols, which are sterols found in plants, assist in reducing high levels of LDL cholesterol in the blood by preventing cholesterol absorption in the intestines. Phytosterols decrease the bioavailability of dietary cholesterol, reducing total cholesterol levels in the body.

1.3.4. Vitamins and minerals:

Vitamins play crucial roles in maintaining health and supporting various metabolic processes in the body.

- Vitamin A is essential for vision, bone development, and maintaining epithelial cells and mucous membranes. Deficiency can lead to night blindness, impaired bone growth, and increased infection susceptibility.
- Vitamin D facilitates calcium and phosphorus absorption, essential for bone health.
- Vitamin E acts as an antioxidant and protects cell membranes from oxidative damage.
- Vitamin K is essential for blood clotting and bone health.
- Ascorbic Acid is an antioxidant, essential for collagen synthesis, and enhances iron absorption.

- Vitamin B Complex is essential for energy metabolism, nerve function, and red blood cell formation.

1.4 THE BIOAVAILABILITY OF NUTRIENTS

Assessing the bioavailability of nutrients is essential for determining their practical usefulness in metabolism. Merely quantifying the quantity of a nutrient in a diet does not automatically indicate its efficacy for the body. Bioavailability is influenced by factors such as the capacity to be digested, absorbed from the intestinal system, and interact with other nutrients. For example, adding iron pellets to cereals may enhance their iron content. However, if the body cannot absorb the iron easily, it contributes no nutritional value. Several factors, such as the food's composition, processing techniques, and individual characteristics like age, sex, and overall health, might affect the availability of nutrients.

Food content, processing, and storage can modify the bioavailability of carbohydrates, proteins, lipids, vitamins, and minerals. As an example, the bioavailability of iron, which is a necessary mineral, can range between 1-10% of its overall concentration in real-world dietary settings. Dietary recommendations aim to account for bioavailability, but due to the intricate nature of the elements involved and the difficulties in evaluation, additional research is necessary to enhance our understanding of how the body utilizes nutrients.

SELF-ASSESSMENT QUESTIONS

(a) Short Questions:

1. What are the primary constituents of food, and how do they contribute to its nutritional value?
2. Explain the role of food scientists in addressing global issues such as malnutrition and food security.
3. How does food serve as an energy source for biological processes, and what factors influence individual caloric needs?
4. Discuss the importance of collaboration between food scientists and nutritionists in ensuring food products meet nutritional standards.

(b) Fill in the blanks

1. Food science is an interdisciplinary study that utilizes ideas from basic sciences and engineering to comprehend the physical, chemical, and biological properties of foods and the processes involved in their _____.
2. Food chemists study the chemical makeup of foods and analyze how their qualities are altered during _____.
3. Carbohydrates, proteins, fats, and their derivatives are the major constituents in foods, along with inorganic minerals and organic substances such as vitamins, enzymes, emulsifiers, acids, antioxidants, pigments, and _____.
4. Foods primarily consist of biochemical derived from living sources, such as plants and _____.
5. Fats typically offer around _____ kilocalories per gram, carbohydrates provide approximately 4 kilocalories per gram, and proteins contribute about 4 kilocalories per gram.

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UNIT -2

CARBOHYDRATES IN FOOD

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INTRODUCTION

Carbohydrates are essential organic molecules of carbon, hydrogen, and oxygen, commonly known as carbohydrates. They include both uncomplicated and intricate molecules, performing crucial functions in the composition and functionality of food. Notable dietary carbohydrates encompass simple sugars, dextrin, starches, cellulose, hemicelluloses, pectin, and gums. Carbohydrates play crucial roles in the diet by providing essential energy and fibre. They also have many functional properties in food applications, including sweetening, thickening, stabilizing, gelling, and acting as substitutes for fat.

LEARNING OBJECTIVES

After studying this unit, you will be able to:

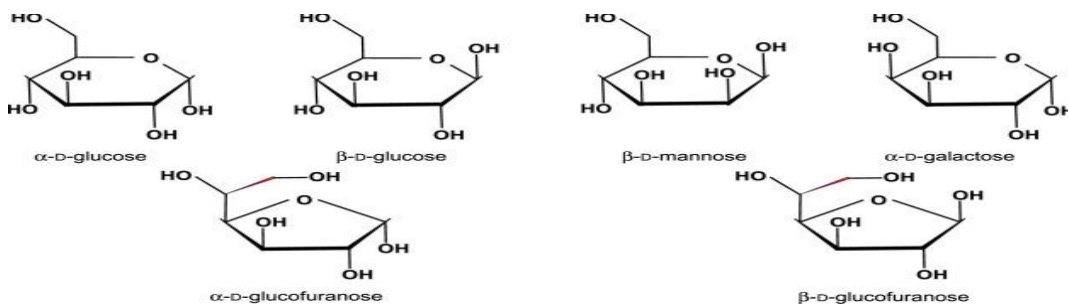
- ✓ To differentiate between various types of carbohydrates and their functions.
- ✓ To explain the physical and chemical properties of sugars and polysaccharides.

2.1 MONOSACCHARIDE

Monosaccharides or sugars, commonly called simple carbohydrates, are composed of three to eight carbon atoms, with five or six carbon atoms being the most prevalent. Glucose and fructose are essential hexose sugars in the diet, with the chemical formula $C_6H_{12}O_6$.

Glucose, a type of sugar known as an aldose, contains an aldehyde group (CHO) located on its first carbon atom. The compound is commonly observed in the D-series arrangement, where the stereochemistry is determined by the carbon atom with the maximum number of asymmetry (carbon-5).

Fructose is a type of sugar that belongs to the ketose group. It has a ketone group attached to its second carbon atom. The compound mostly takes on furanose configurations and is present in alpha (α) and beta (β) anomers. Unlike glucose, Fructose does not have an aldehyde group and is only found in the d-series structure. Comprehending monosaccharides' structural arrangements and characteristics is essential, as they impact diverse physiological and functional aspects in food systems.



2.2 DISACCHARIDES

Disaccharides, formed by the linkage of two monosaccharide units by a glycosidic bond, are important components of several foods. Specifically, sucrose, maltose, and lactose are of significant importance.

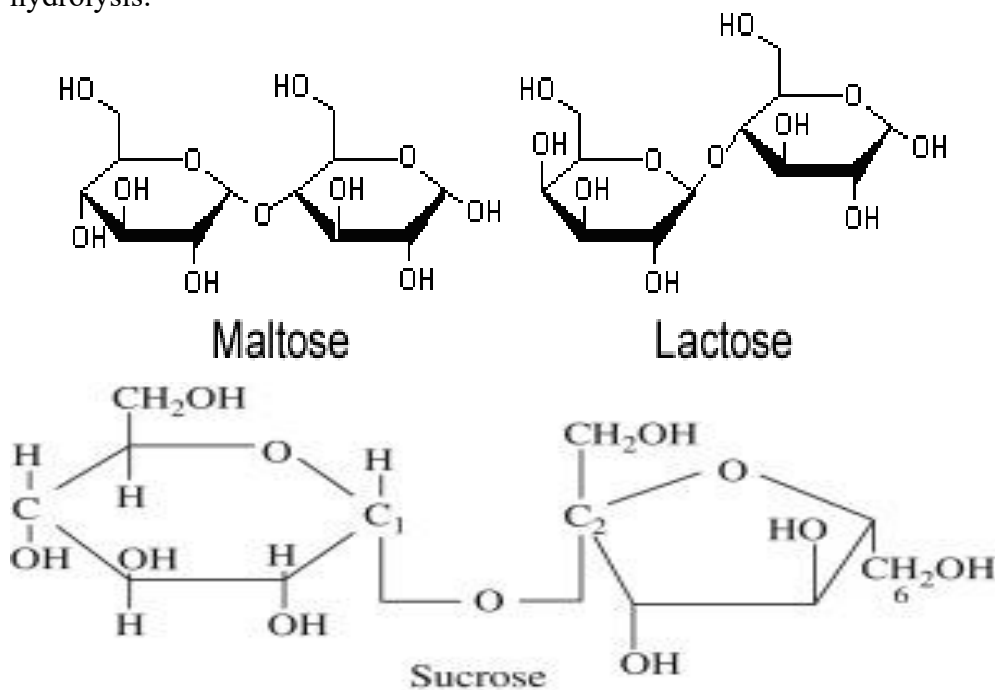
2.2.1. Glycosidic bond: A glycosidic bond is formed through the reaction between one monosaccharide's carbonyl group and another's hydroxyl group. This reaction removes water. Glycosidic linkages are typically stable but can be broken down through hydrolysis caused by acid, heat, or certain enzymes like sucrase, invertase, or amylases.

2.2.2. Sucrose: Sucrose also referred to as table sugar is composed of glucose and fructose molecules that are connected by an α -1,2-glycosidic bond. This bond forms

between the carbonyl groups of glucose and fructose, determining the arrangement of each monosaccharide. Glucose is immobilized in the α -configuration, whereas fructose is immobilized in the β -configuration. Enzymatic action or exposure to heat and acid can cause sucrose to undergo hydrolysis, forming its constituent monosaccharides, glucose and fructose.

2.2.3. Maltose : Maltose is a significant disaccharide composed of two glucose units connected by an α -1,4-glycosidic bond. This connection stabilizes the arrangement of the initial glucose molecule in the α -position. Maltose is a fundamental component of starch, which likewise consists of α -1,4-glycosidic linkages, allowing it to be easily broken down by the human body during digestion.

2.2.4. Lactose : Lactose, a disaccharide present in milk and frequently referred to as milk sugar, is composed of glucose and galactose molecules connected by a β -1,4-glycosidic linkage. The bond structure of lactose results in a reduced level of sweetness and solubility compared to other sugars. Due to the β -configuration of lactose's glycosidic bond, it is indigestible for many persons as the β -linkages cannot be broken down by digestive enzymes, unlike maltose. Lactose intolerance is caused by the inability to break down lactose into its monosaccharides by hydrolysis.



2.3 SOME PROPERTIES OF SUGARS

Sugars have several characteristics crucial in food science and technology, encompassing attributes such as sweetness, preservation, and fermentation. Below are a few significant characteristics of sugars:

2.3.1. Sweetness: Different sugars, such as glucose, fructose, and sucrose, have varying sweetness levels. Fructose is the sweetest, while lactose (milk sugar) is the least sweet. This characteristic renders sugars highly valuable as sweeteners in many food products.

2.3.2. Fermentation: Sugars are readily ingested and metabolized by both humans and microorganisms. During the process of bread making, yeast cells undergo fermentation of sugar, resulting in the production of carbon dioxide. This carbon dioxide is responsible for leaving the dough and causing it to rise when it is baked.

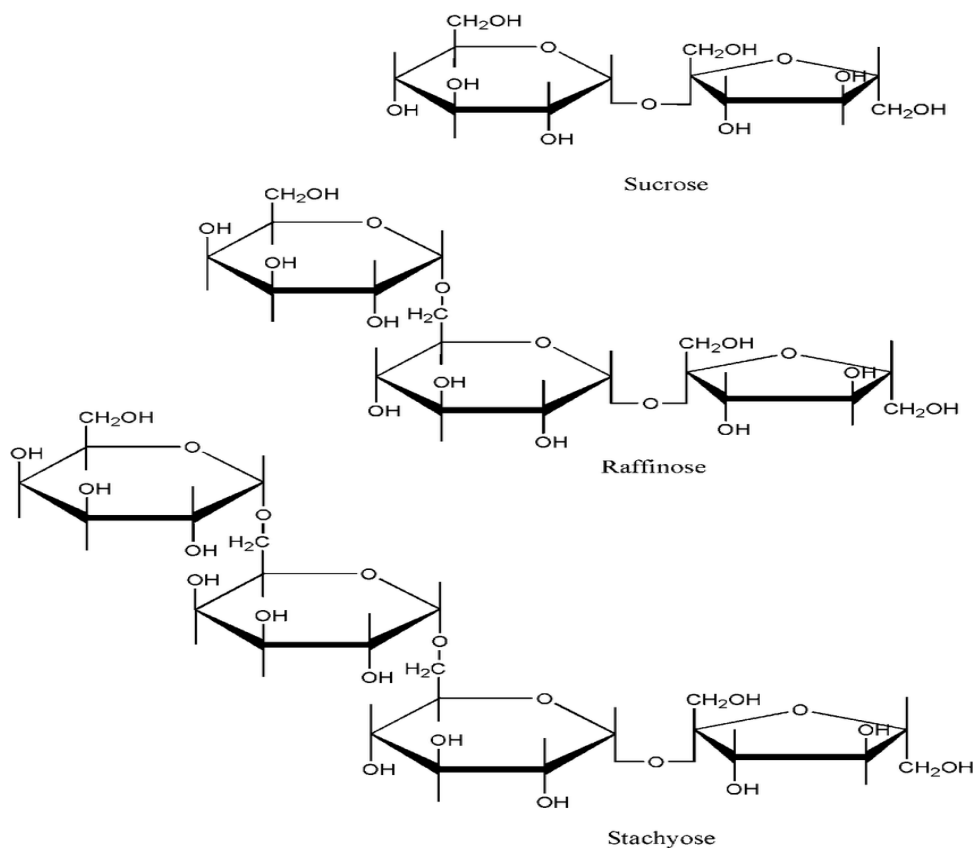
2.3.3. Preservation: Elevated levels of sugars decrease the water activity of food, hence inhibiting the growth of microorganisms. Sugars can function as preservatives and are frequently employed in preserving foods such as jams and jellies.

2.4 OLIGOSACCHARIDES

Oligosaccharides are carbohydrates with a limited number of monosaccharide units, usually between 3 and 10, connected by glycosidic linkages. Raffinose and stachyose are two common oligosaccharides found in legumes like dry beans and peas.

2.4.1. Raffinose: Raffinose is a Trisaccharide's composed of galactose, glucose, and fructose. The human digestive system cannot break down or convert it into simpler substances because it lacks the necessary enzymes. Instead, Raffinose remains intact as it passes through the small intestine and reaches the large intestine, a source of nutrition for bacteria.

2.4.2. Stachyose: Stachyose is an oligosaccharide that is present in legumes. It is similar to raffinose, but it has one extra galactose unit. The composition of the substance includes glucose, fructose, and two interconnected galactose units. Like raffinose, stachyose is indigestible in the human digestive system and remains intact as it passes through to the large intestine. The fermentation of stachyose by bacteria in the colon leads to gas production, which might result in gastrointestinal discomfort.



2.5 POLYSACCHARIDES

Polysaccharides are complex carbohydrate molecules composed of extended chains of monosaccharide units connected by glycosidic linkages. Starches, pectins, and gums are significant polysaccharides found in food. Each of these polysaccharides has unique qualities defined by its specific composition and structure.

2.5.1 Dextrins and dextrans

Dextrins are glucose polymers of intermediate length that are produced by partially hydrolyzing starch. They are higher in size compared to oligosaccharides but are shorter in length than whole starch molecules. Dextrins are composed of glucose molecules connected by α -1,4-glycosidic linkages, resulting in the formation of linear polymers. They are frequently present in corn syrups that are created through the process of starch hydrolysis.

Dextrans are glucose polymers with α -1,6-glycosidic linkages that are of intermediate length. Specific bacteria and yeasts produce them through synthesis.

2.5.2 Pectins and other polysaccharides:

Pectins are naturally occurring long-chain polymers of α -D-galacturonic acid generated from galactose, found in fruits and vegetables. These substances may dissolve in water and are employed as gelling agents, stabilizers, and thickeners in various culinary items such as jellies and jams.

Gums: Gums, such as gum tragacanth and guar gum, are complex polysaccharides with extensive branching obtained by extracting them from plants. They create thick and stable solutions and are used as thickening agents and stabilizers in food, especially low-fat goods.

Seaweed polysaccharides, such as agars, alginates, and carrageenan, are obtained from seaweed and serve as gelling agents, thickeners, and stabilizers in food items. These substances are categorized as gums and can create gels, which is not common among most gums.

Cellulose and hemicellulose are polysaccharides that play a crucial role in providing support to plant tissues and are essential constituents of dietary fiber. Although they are not metabolized in the human body, they enhance digestive well-being by serving as indigestible dietary fiber.

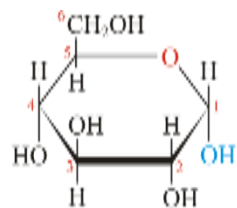
2.5.3 Starches in Food

Starch, a complex carbohydrate found in plants, is a vital source of energy stored in the roots, seeds, and grain kernels. The brain and neurological system rely on it as a crucial supply of glucose. Starch granules, which consist of glucose polymers with long chains, are not soluble in water and function as efficient thickeners when subjected to heat. Various varieties of starches and altered starches have distinct functions in food products, such as enhancing viscosity, preventing coagulation, and providing stability to cooked foods.

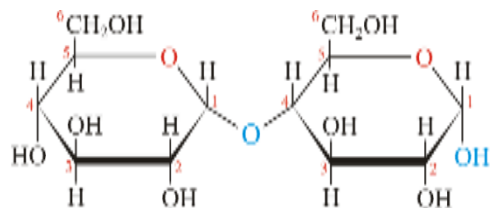
Sources

Starch can be obtained from several plants, such as cereal grains like wheat, corn, and rice. Every source produces starch with distinct qualities appropriate for various culinary uses. In addition, legumes, tubers such as cassava and potatoes, and specialized starches offer alternate sources of starch. The structure and composition of starch can vary in terms of the size and form of the starch granules, which are dependent on the source of the starch. Starch comprises two primary molecules, amylose and amylopectin, which are connected by glycosidic linkages. Amylose makes up about 25% of starch and creates straight chains that cause

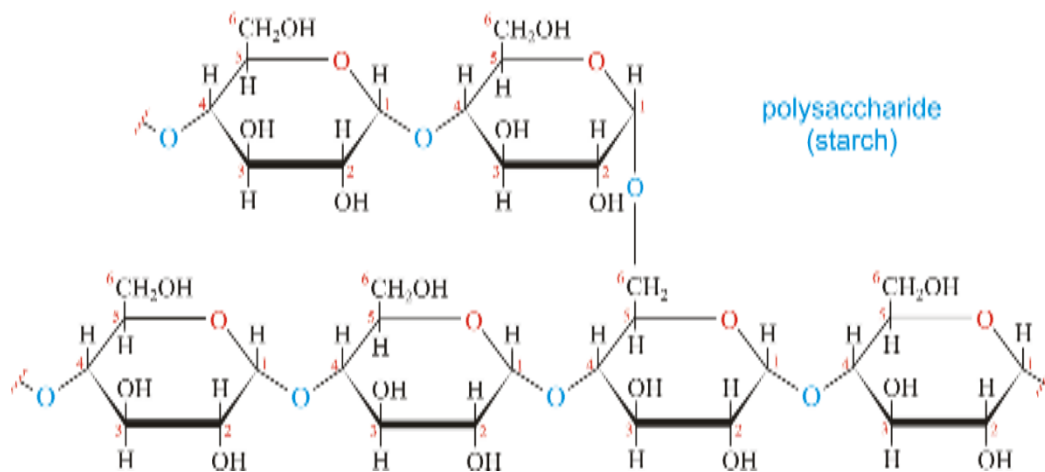
gelation when cooled. Amylopectin, the primary constituent, is extensively branched and plays a significant role in the thickening characteristics of starch.



monosaccharide
(glucose)



disaccharide
(maltose)



polysaccharide
(starch)

SELF-ASSESSMENT QUESTIONS

Multiple choice questions:

1. What are the two most prevalent hexose sugars in the diet?
a) Glucose and fructose b) Sucrose and lactose c) Glucose and galactose d) Maltose and lactose
2. What is the primary function of oligosaccharides such as raffinose and stachyose?
b) Providing sweetness b) Serving as a source of nutrition for bacteria c) Acting as a thickening agent d) Enhancing food preservation
3. Which polysaccharide is known for supporting plant tissues and is considered an essential dietary fiber?
c) Pectin b) Gum c) Cellulose d) Starch

Short questions:

1. What are some characteristics of sugars that are important in food science?
2. What is the primary function of carbohydrates in the diet?
3. What is the glycosidic bond?
4. What is the significance of oligosaccharides like raffinose and stachyose in legumes?
5. How do starches contribute to the characteristics of food items?

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UNIT -3

PROTEINS IN FOOD

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INTRODUCTION

Proteins comprise a substantial amount of biological matter, frequently surpassing 50% of the weight of cells when they are dried. These molecules are essential for various biological processes because of their distinct forms and shapes, which allow them to perform specific duties within living organisms. Proteins have a wide range of functions in biological systems, including forming complex muscle and connective tissue systems and acting as transporters in circulation. All enzymes, serving as catalysts for biochemical events, are proteins that significantly impact various processes in food and biological systems.

LEARNING OUTCOMES+

After studying this unit, you will be able to:

- ✓ To identify the structure and functions of amino acids and proteins.
- ✓ To understand enzyme activity and its applications in food processing.

3.1. PROTEIN COMPOSITION

Proteins consist of carbon, hydrogen, nitrogen, and oxygen, and some additionally include sulfur and other elements such as phosphorus, iron, copper, and zinc. Amino acids function as the fundamental constituents of proteins, comprising a minimum of 20 distinct varieties in the natural world. The distinctive organisation of amino acids results in the specific structure, conformation, and function of every protein molecule. Even slight modifications, such as adjustments in pH or temperature, can cause substantial modifications in protein molecules, as seen in different food processing methods such as cheese-making and egg preparation.

3.2. THE SIGNIFICANCE OF PROTEINS IN FOOD

Proteins have essential nutritional and physiological functions in foods, making a considerable contribution to their texture and overall quality.

3.2.1. Amino Acids

Amino acids, which are the fundamental components of proteins, possess a shared structural framework that is defined by a core carbon atom (α -carbon) connected to four different groups: a carboxyl group (COOH), an amino group (NH₂), a hydrogen atom, and a side chain represented as R. The distinctive side chain present in each amino acid is responsible for determining its specific characteristics and roles. Glycine, the most essential amino acid, has a hydrogen atom as its side chain, whereas other amino acids have more intricate side chains. More than 20 distinct amino acids in proteins lead to a wide range of molecular properties due to differences in their side chain compositions.

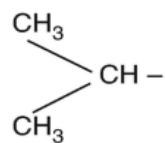
Amino acids in aqueous solutions at pH 7 mainly exist as zwitterions, where the amino and carboxyl groups are ionised, forming COO⁻ and NH₃⁺ groups, respectively. Amino acids possess an amphoteric character, allowing them to function as both acids and bases depending on the pH circumstances in their environment. Amino acids can donate or absorb protons, thereby demonstrating both acidic and basic characteristics.



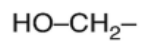
Alanine



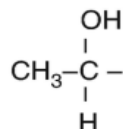
Glycine



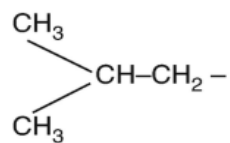
Valine



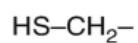
Serine



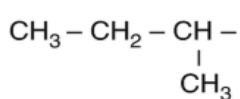
Threonine



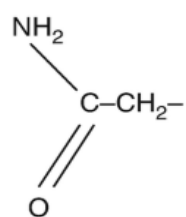
Leucine



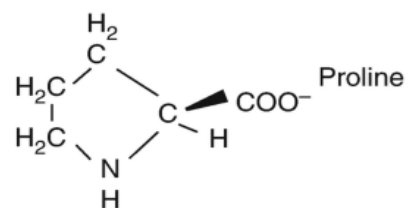
Cysteine



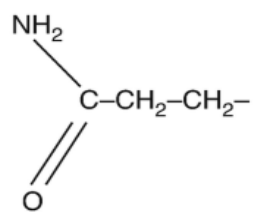
Isoleucine



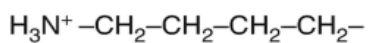
Asparagine



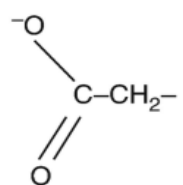
Proline



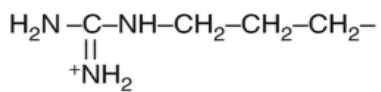
Glutamine



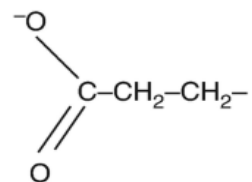
Lysine



Aspartic Acid



Arginine



Glutamic Acid

Amino acids can be classified based on their chemical properties and structures.

3.2.1.1. Non-polar Amino Acids

This category consists of amino acids that possess nonpolar, hydrophobic side chains, making them water-resistant. Some examples of amino acids are alanine, valine, leucine, proline, and methionine. Their hydrophobic properties enable interactions inside proteins to reduce contact with water-based surroundings.

3.2.1.2. Polar Amino Acids

Amino acids in this category have polar, hydrophilic side chains, which means they have an affinity for water. Serine, glutamine, and cysteine are exemplary members. These amino acids possess hydroxyl, amide, or thiol groups in their side chains, enabling them to engage in hydrogen bonding interactions inside proteins. Cysteine is renowned for its capacity to create disulfide bonds, which significantly improve the stability of proteins.

3.2.1.3. Positively charged basic Amino Acids

Lysine, arginine, and histidine are examples of basic amino acids that possess amino groups with a positive charge. At a pH of 7 (neutral), these amino acids carry a positive charge, which helps them interact with negatively charged components inside proteins or the surrounding environment.

3.2.1.4. Negative Charged Acidic Amino Acids

Aspartic and glutamic acids are examples of acidic amino acids that include additional carboxyl groups. This causes them to have a negative charge at a pH level that is neither acidic nor basic. This charge allows them to engage with positively charged substances through ionic bonds or salt bridges, affecting protein structure and function.

3.3. PROTEIN STRUCTURE AND PROPERTIES OF PROTEINS

Protein structure comprises peptide bonds, which bind amino acids together. Peptide bonds are strong and difficult to break; however, an acidic or enzymatic digestion process can hydrolyze proteins into smaller polypeptides. Comprehending the amino acid sequence, which defines proteins' fundamental structure, is essential to understanding their overall structure and function.

3.3.1. Primary structure:

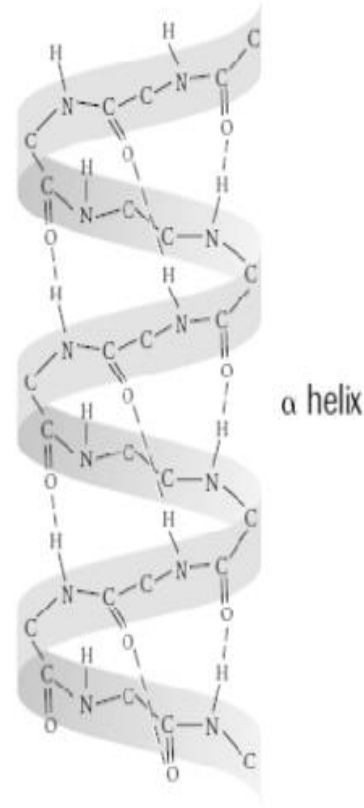
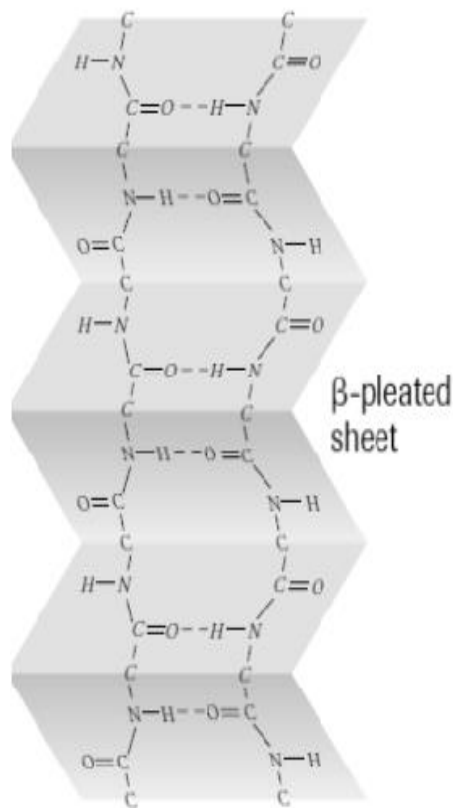
The fundamental structure of a protein refers to the precise organisation of amino acids that are linked together by peptide bonds along the protein chain. This linear sequence acts as the basis for the following layers of protein structure. Despite not existing as linear chains, proteins acquire their overall spatial shape based on their fundamental structure.

3.3.2. Secondary structure:

Secondary structure refers to the local folding patterns of a protein or nucleic acid molecule, precisely the arrangement of its amino acid or nucleotide residues.

The secondary structure pertains to the spatial arrangement of segments inside the polypeptide chain. Notable secondary constructions include:

- An alpha helix is a tightly coiled structure held together by hydrogen bonds within the same chain.
- A beta-pleated sheet is a stretched-out arrangement created by hydrogen bonding between chains.
- Random Coil is a pliable and disorganised structure that arises from uneven groupings of amino acids. The occurrence of alpha helices, beta-pleated sheets, or random coils along the protein chain is determined by the fundamental structure.



3.3.3. Tertiary structure:

The overall three-dimensional organization of the protein chain is referred to as the tertiary structure. There are two kinds of tertiary structures seen in proteins:

- Fibrous proteins
- Globular proteins

3.3.3.1. Fibrous proteins

Fibrous proteins, such as collagen (a protein found in connective tissue) and actin/myosin (responsible for muscle contraction), are distinguished by their elongated and fibrous architecture. These proteins arrange themselves in elongated sequences, leading to the formation of either rods or fibres. Fibrous proteins generally exhibit a significant level of organized secondary structure, predominantly composed of alpha-helices or beta-sheets.

3.3.3.2. Globular proteins

On the other hand, globular proteins assume a condensed, round, or oval form. Some examples of globular proteins are myoglobin, which plays a role in transporting oxygen to muscles, whey proteins, and caseins, which are present in milk. Globular proteins exhibit a tertiary structure that is enhanced by a substantial abundance of hydrophobic amino acids, which aggregate towards the core of the protein. This configuration promotes hydrophobic interactions between these amino acids, which helps to stabilise the protein's condensed structure.

3.3.4. Quaternary Structure:

Quaternary structure refers to the arrangement and interactions of several protein subunits to form a functional protein complex. Protein quaternary structure refers to the noncovalent bonding between protein chains, which may or may not be indistinguishable. Quaternary structure is observed in the actomyosin system of muscles and the casein micelles of milk. To obtain additional information regarding these structures, please see the respective chapters on meat and milk.

3.4. PROPERTIES OF PROTEINS

Proteins exhibit a wide range of reactions and features that are essential to their structure, function, and behaviour in many situations, such as food processing and preservation. These responses are crucial for managing the excellence, consistency, and nutritional value of food items.

3.4.1. Amphoteric nature

- Amphoteric nature refers to the ability of a substance to act as both an acid and a base. Proteins, similar to amino acids, have amphoteric characteristics, indicating their ability to function as both acids and bases depending on the pH level of their surroundings. Proteins possess an amphoteric nature, which allows them to withstand pH fluctuations and grants them the ability to act as buffers.

3.4.2. Water-Binding Capacity

- **Water Interaction:** Proteins can bind water molecules by interacting with their backbone and polar or charged side chains. The degree of water binding is dependent on the amino acid residues, where charged and polar groups facilitate water binding, whereas hydrophobic groups deter water.
- **Influence of pH on Water Binding:** The water-binding capabilities of proteins vary depending on their proximity to their isoelectric point. Proteins exhibit reduced water affinity as their charge decreases, resulting in a lower binding of water molecules, particularly when closer to the isoelectric point.

3.4.3. Denaturation

It is the process of altering the structure of a molecule, often a protein, resulting in the loss of its biological activity. Denaturation refers to the disturbance of secondary, tertiary, and quaternary protein structures while leaving the primary structure unchanged. This phenomenon commonly arises due to several circumstances, including elevated temperature, pH alterations, ionic strength fluctuations, freezing, or mechanical agitation. The denaturation mechanism involves the disruption of hydrogen bonds and other non-covalent interactions, resulting in the unfolding of the protein and the exposure of previously hidden hydrophobic areas. Proteins that have been denatured frequently undergo precipitation and lose their functional qualities, such as enzymatic activity.

3.4.4. Peptides and proteins hydrolysis

Hydrolysis is a process in which proteins can be broken down by cleaving the peptide bonds, resulting in the formation of smaller peptide chains or free amino acids. This process can be accelerated by enzymes or acids and is crucial in food preparation to soften meat or produce cheese.

3.4.5. Maillard browning reaction

The Maillard reaction is a nonenzymatic browning process that occurs between reducing sugars and amino acids at high temperatures. This chemical reaction results in the formation of brown pigments and plays a role in the taste and appearance of baked foods. Maillard browning is favored by high quantities of sugar and protein, increased temperatures, alkaline pH, and low water content. It is particularly important in the field of food processing, especially in goods that are susceptible to browning.

3.5. ENZYMES

Enzymes, being specialised proteins, have crucial functions in food processing by accelerating many biochemical reactions that impact the quality, color, flavour, and texture of foods.

3.5.1. Function and Structure

- Enzymes play a role as catalysts in biochemical reactions, speeding up the reactions without being used up in the process. They enable both beneficial and detrimental changes in food constituents, impacting the overall quality of the product.
- Enzymes exhibit specificity by having a distinct three-dimensional configuration that enables them to selectively attach to their substrate, thereby beginning and facilitating a specific biochemical reaction.
- Enzymes demonstrate maximum efficiency within temperature and pH ranges. Enzymes can become ineffective in catalyzing processes if they deviate from these ranges, as this can cause them to denature.

3.5.2. Enzymatic Reactions

Desirable enzymatic processes in food processing are regulated to ensure the most favourable environment for enzyme activation. Instances of this phenomenon include the coagulation of milk in the process of cheese making, the maturation of fruits, and the softening of meat through the use of proteolytic enzymes. Attaining the ideal pH and temperature range is essential for increasing enzyme activity. Heat treatment can be used to deactivate unwanted enzymes or adjust the pH by adding acids to suppress enzymatic activity.

3.5.3. Examples of Enzymatic Reactions

1. Cheese production involves the use of rennet, an enzyme that plays a crucial role in initiating the coagulation of milk, which is a vital stage in the process of manufacturing cheese. Moreover, the presence of enzymes plays a significant role in the process of cheese ripening, resulting in the improvement of both taste and consistency.
2. Meat tenderization is achieved through the action of proteolytic enzymes such as papain and bromelain, which break down protein bonds in the meat. Regulating the duration and circumstances of enzyme activity is crucial to avoid excessive degradation of proteins.

3.6. Functional Roles of Proteins in Foods

Proteins provide significant functional roles in food products, adding to their texture, stability, and overall quality.

- Protein solubility is dependent upon the specific amino acid composition and sequence of the protein. Proteins such as whey have a strong ability to

dissolve, particularly in acidic conditions, which makes them well-suited for enriching drinks and improving their nutritional content. Proteins provide essential amino acids and contribute to the nutritional profile of foods, supporting the growth, repair, and maintenance of body tissues.

- Egg and animal proteins are frequently employed as thickening agents in a variety of culinary items, imparting viscosity and texture.
- Binding agents, such as proteins found in eggs and meat, provide robust cohesive qualities that contribute to the structure and integrity of food formulations.
- Gelling agents such as gelatin, egg white proteins, and gluten proteins play a role in creating gels in food, which gives them a solid and stable texture. Gelatin gels are dependent on hydrogen bonds, whereas egg white gels are formed by hydrophobic interactions and disulfide bonds.
- Emulsification and foaming are processes in which proteins, like egg yolk proteins and milk caseins, operate as emulsifiers. They stabilise emulsions by creating a protective coating between two phases that are not easily mixed, such as oil and water.
- Egg white proteins are well-known for their capacity to create stable foams by trapping air bubbles inside a protein matrix. This characteristic adds texture and volume to baked items and desserts.
- Texture Control Proteins play a crucial role in altering the texture of food products by thickening, gelling, or emulsifying. This, in turn, affects the way the food feels in the mouth and the overall sensory experience.

Precise processing and careful handling are necessary to maintain the functionality of proteins. Controlled denaturation is necessary to obtain specific textural characteristics; however, excessive denaturation can result in undesired effects such as emulsion splitting, foam instability, or gel syneresis. Proteins have many roles in food systems, providing a wide range of functional features that are used to create different food products with unique textures, structures, and sensory characteristics. By carefully controlling protein behaviour, food engineers can enhance product formulations to satisfy consumer preferences and meet high-quality standards.

SELF-ASSESSMENT QUESTIONS

Short questions:

1. How are amino acids classified based on their chemical properties?
2. How do fibrous proteins differ from globular proteins in terms of structure and function?
3. Describe the quaternary structure of proteins and provide an example of a protein complex.
4. What factors contribute to protein denaturation, and how do they affect protein structure?
5. How do enzymes function in biochemical reactions, and what factors influence their activity?

Mark the statement as true or false

1. Proteins consist primarily of carbon, hydrogen, nitrogen, and oxygen, with sulfur and other elements occasionally present. **(true/false)**
2. Amino acids have an amphoteric character, meaning they can act as both acids and bases depending on the pH of their environment. **(true/false)**
3. Fibrous proteins, such as collagen, typically have a globular shape and are soluble in water. **(true/false)**
4. Denaturation is altering a protein's primary structure while leaving its secondary, tertiary, and quaternary structures unchanged. **(true/false)**
5. Food preservation methods such as blanching, can prevent enzymatic activity in fruits and vegetables before freezing. **(true/false)**

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UNIT -4

FATS AND OIL PRODUCTS

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INTRODUCTION

Fat is an essential component of the human diet. It is highly valued for its capacity to improve the taste, texture, and overall appeal of food products through its influence on flavour, mouthfeel, palatability, and scent. Fats not only possess sensory qualities but also function as vehicles for crucial fat-soluble vitamins A, D, E, and K. These fats and oils can come from animals, plants, or the ocean and are commonly mixed during industrial processing. Fats generally undergo solidification at normal temperatures, whereas oils maintain their liquid state. Specific fatty acids, such as linolenic and linoleic acids, are considered necessary since the body is unable to produce them in adequate amounts. Fats and oils are hydrophobic substances, meaning they do not dissolve in water. This property gives them a distinct oily texture that customers may observe on napkins or dinner plates. During the process of processing, fats can transform into monoglycerides and diglycerides. These substances are commonly added to food products as emulsifiers.

LEARNING OBJECTIVES

After studying this unit, you will be able to:

- ✓ To describe the chemical structure and properties of fats and oils.
- ✓ To understand the processes of fat oxidation and rancidity

4.1. STRUCTURE AND COMPOSITION OF FATS

4.1.1. Glycerides:

Glycerides, including monoglycerides, diglycerides, and triglycerides, are important in food science and nutrition. Below is an analysis of their composition and roles:

Monoglycerides and diglycerides function as emulsifiers in food, aiding in blending water- and fat-based components. Monoglycerides are single fatty acid molecules bonded to glycerol, whereas diglycerides are two fatty acid molecules bonded to glycerol.

Triglycerides are the predominant form of glycerides in diets, constituting more than 95% of the fatty compounds. Oils and fats, known as lipids, are hydrophobic substances that cannot dissolve in water. They can exist as either liquids or solids at ambient temperature.

The structure of glycerides consists of a glycerol molecule acting as a central framework, with fatty acid molecules linked to it. A monoglyceride is formed when glycerol undergoes esterification with a single fatty acid molecule. When two fatty acids combine, they generate a diglyceride through esterification. Triglycerides are formed by the process of esterification, where glycerol combines with three fatty acid molecules.

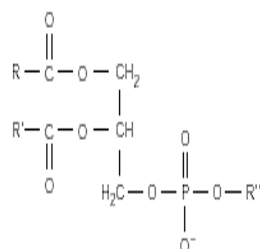
4.1.2. Phospholipids:

Phospholipids resemble triglycerides, but instead of the third fatty acid, they have a nitrogen-containing group in place of the polar group that contains phosphoric acid, and only two fatty acids esterified to glycerol. The most prevalent phospholipid is lecithin, which can be found in soybeans and egg yolk among other foods. It is utilized in many food products and functions as an emulsifier, making mixing fat and water easier.

4.1.3. Sterols:

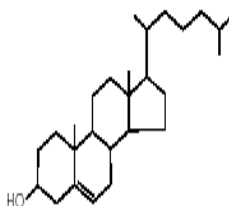
Sterols have a characteristic round shape and are defined by an alcohol group, an 8–10 carbon side chain, and a common steroid nucleus. The main sterol in animals is cholesterol; sitosterol and stigmasterol are examples of plant sterols or stanols. They are present in many dietary products, such as spreads that resemble margarine, and they have roles in the construction and function of cells.

Phospholipids

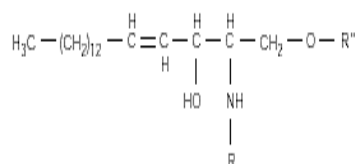


R, R', Hydrocarbon chains of fatty acids
R'', Head-group

Cholesterol



Sphingolipids



4.1.4. Cis and Trans Configurations:

Unsaturated fatty acids can have double bonds in the Cis or Trans form. The hydrogen atoms connected to the double bond's carbon atoms are on the same side in the cis form and on opposite sides in the Trans configuration. Cis double bonds cause a bend in the chain, which modifies characteristics such as melting points. Trans fatty acids do not considerably change the molecule's linear structure and have a higher melting point than cis variants.

4.2. PROPERTIES OF FATS AND OILS

4.2.1. Crystal formation:

As fats cool, the kinetic energy reduction enables their molecules to attract one another through weak but important Van der Waals forces, especially in those with longer or larger chains. This attraction promotes the arrangement and connection of fat molecules into a well-organized lattice, which is known as crystallization.

4.2.2. Polymorphism:

Polymorphism is the property of lipids that undergo crystallization in several forms. The four main polymorphic forms are alpha (α), beta prime (β'), intermediate, and beta (β). Alpha crystals have the smallest size and lowest stability and rapidly transition to more stable forms. In contrast, beta crystals are the most stable, largest in size, and possess the highest melting points. The crystallization process can modify the size of the crystals. Rapid cooling with agitation tends to produce more smaller crystals, as opposed to slower production of larger ones.

4.2.3. Melting point:

The melting point of fats and oils is a vital indicator of the level of molecular attraction present in them. Essentially, it indicates the degree of molecular cohesion in a substance, determining the ease with which it forms a solid structure and the

resistance to converting it into a liquid condition. A higher melting point indicates greater intermolecular forces, implying a more compact arrangement of molecules. Longer-chain fatty acids exhibit elevated melting points compared to their shorter-chain counterparts because they possess a greater capacity for intermolecular interaction. The increased attraction results from the cumulative impact of longer chains, similar to the interlocking teeth of a zipper. As an example, butyric acid (4:0) has a comparatively low melting point of 18°F (-7.9°C), whereas stearic acid (18:0) has a significantly higher melting point of 157°F (69.6°C).

4.3 COMPOSITION OF DIETARY FATS AND OILS

The table presents a comprehensive analysis of the fatty acid makeup of different fats and oils typically used in food preparation. These fats are classified according to their levels of saturated, polyunsaturated, and monounsaturated fats, each having unique properties and nutritional implications.

DIETARY FAT	Fatty acid content normalized to 100 per cent			
	Saturated	Polyunsaturated	Alpha Linolenic	Monounsaturated
Canola oil	7%	21%	11%	61%
Safflower oil	10%	76%	Trace	14%
RSunflower oil	12%	71%	1%	16%
Corn oil	13%	57%	1%	29%
Olive oil	15%	9%	1%	75%
Soybean oil	15%	54%	8%	23%
Peanut oil	19%	33%	Trace	48%
Cottonseed oil	27%	54%	Trace	19%
Lard*	43%	9%	1%	47%
Beef tallow*	48%	2%	1%	49%
Palm oil	51%	10%	Trace	39%
Butterfat*	68%	3%	1%	28%
Coconut oil	91%	2%	7%	

*Cholesterol Content (mg/Tbsp): Lard 12; Beef tallow 14; Butterfat 33. No cholesterol in any vegetable-based oil.

Polyunsaturated fats, primarily derived from plants, are liquid at normal ambient temperature. Prominent instances encompass safflower oil, sunflower oil, soybean oil, and corn oil. Safflower oil has the highest polyunsaturated fat content at 76%, followed by sunflower at 71%, soybean at 54%, and corn at 57%. It is important to mention that "partially hydrogenated" oils undergo hydrogenation to boost their saturation levels.

Monounsaturated fats, which remain in liquid form at room temperature, are mostly obtained from plants and are linked to positive effects on health, such as

decreasing serum cholesterol levels and lowering the likelihood of developing coronary heart disease. Prominent examples include olive oil, high-oleic safflower, and canola (rapeseed oil). Olive oil has the largest concentration of monounsaturated fat, with a content of 75%. It is followed by high-oleic safflower oil, which has a content of 80%, and canola oil, which has a content of 61%.

Saturated fats, solid at normal room temperature, are primarily present in animal-based sources, although certain tropical oils also include them. Saturated fats are known to increase levels of cholesterol in the bloodstream. Some examples of fats include lard, cow tallow, palm oil, butterfat, and coconut oil. Animal fats often contain saturated fatty acids, primarily composed of 18-carbon chains.

4.2.4. Fat modification:

Various methods are used to modify fats to improve their functionality and change some aspects of their properties to fulfil food production requirements.

4.2.5. Hydrogenation:

Hydrogenation is a typical procedure to decrease the number of double bonds in unsaturated fatty acids. Liquid oils are converted to semisolid or plastic fats for two reasons: to change the fat's physical characteristics and to make it more stable against oxidation and heat, which lengthens the fat's shelf life. Trans fatty acids are usually produced during hydrogenation, raising the fat's melting point and adding to its firmness. Partly hydrogenation is frequently chosen to maintain some unsaturation and strike a compromise between stability and health concerns.

4.2.6. Acetylation:

Acetylation is the process by which acetic acid replaces one or two fatty acids in a triglyceride, creating acetoglycerides or acetin fats. Depending on the fatty acids that make up the fat, acetone fats can have different physical states at room temperature. Including acetic acid lowers the fat's melting point and encourages the development of stable β -crystals. Acetyl fats are used in some foods as coating agents and edible lubricants to stop moisture loss.

4.3. DETERIORATION OF FATS

Fats can degrade through two primary mechanisms: absorbing smells and undergoing rancidity. The absorption of scents by fats is evident through alterations in taste and aroma, such as when the fat in chocolate assimilates the whiff of smoke in a confectionery or the fragrance of soap in a shopping bag. Butter, for instance, tends to absorb refrigerator odors readily. Processing can mitigate the progression

of degradation, but it does not eliminate the risk. Rancidity, a prevalent fat degradation, manifests in two distinct manners: hydrolytic and oxidative.

4.3.1. Hydrolytic Rancidity:

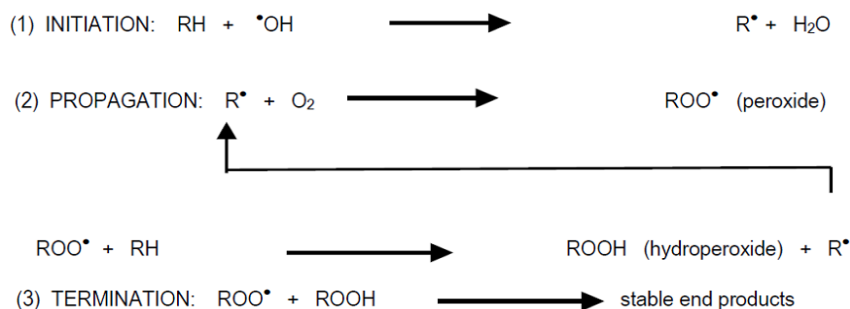
Hydrolytic rancidity occurs when triglycerides react with water, resulting in the liberation of fatty acids from glycerol. The process is facilitated by applying heat and the presence of lipases, which are enzymes. Butter left at room temperature can undergo oxidation, producing volatile short-chain fatty acids such as butyric acid, which can cause the butter to emit a rotten odour. Introducing wet items into hot fat during deep-fat frying can increase the danger of hydrolytic rancidity, which causes the oil to break down further. To avoid this, it is advisable to store fats in cool and dry environments and take measures to deactivate lipases.

4.3.2. Oxidative rancidity, or autoxidation:

Oxidative rancidity, or autoxidation, is the main form of rancidity that impacts fats and oils. Lipid oxidation is the result of unsaturated fatty acids undergoing a chemical reaction that can cause the formation of undesirable tastes and smells. Unsaturated fatty acids containing double bonds are more susceptible to oxidation, which increases their likelihood of becoming rancid.

During the **initiation stage**, the displacement of a hydrogen atom close to a carbon atom with a double bond results in the formation of a free radical. This process generates an unstable and highly reactive species. Factors such as heat, light, metals, and enzymes catalyse this reaction. Free radicals serve as the initial catalyst for the process of oxidation.

During the **propagation stage**, the unpaired electrons of the free radicals combinewith oxygen molecules to create activated peroxides. Subsequently, these peroxides have a reaction with more unsaturated fatty acids, generating additional free radicals and sustaining the process of oxidation. This process persists, resulting in the oxidation of several unsaturated fatty acids.



4.3.3. Prevention of autoxidation:

Ensuring the prevention of autoxidation in fats and oils is essential for preserving their quality and extending their shelf life. Various techniques might be utilized to prolong or impede the oxidation process:

- Optimal storage conditions for fats and oils involve keeping them in a cold and dark location to reduce their exposure to heat and light, as these factors speed up the process of oxidation. Enclosed containers restrict the amount of oxygen available, while vacuum packaging additionally regulates the amount of oxygen that comes into contact with the contents.
- Sequestering chemicals, such as EDTA or citric acid, can be used to bind metals and prevent them from accelerating autoxidation.
- Antioxidants are substances that inhibit oxidation by providing hydrogen atoms to fatty acid-free radicals, so interrupting the chain reaction that causes rancidity. Commonly used phenolic antioxidants include BHA, BHT, TBHQ, and propyl gallate. These antioxidants can be added to enhance their efficacy.
- Tocopherols, which are natural antioxidants present in vegetable oils, might be included as an additional measure to inhibit oxidation. Utilising a blend of antioxidants can augment its efficacy.

4.4. SHORTENING AND SHORTENING POWER OF VARIOUS FATS AND OILS

Shortening is essential in baking as it significantly impacts baked goods' texture, structure, and flavour. Here is an explanation of how various fats and oils work as shortenings:

4.4.1. Lard:

Lard is a substance made from animal fat, known for its prominent crystal structure, and is composed of fatty acids. It produces flaky results when included in baking, especially in pie crusts or biscuits.

4.4.2. Butter and margarine:

Butter and margarine both consist of fats or oils and water. The presence of water diminishes their capacity to contract as much as pure fats. When butter or margarine is utilized in baking, the presence of water causes the starch to become hydrated, resulting in baked foods that are firmer and less tender.

4.4.3. Margarine:

Margarine, created as a replacement for butter, may include cultured skim milk or whey, different types of fats, emulsifiers, and colorants. The fat content of margarine can differ, with certain kinds of margarine containing a significant amount of polyunsaturated fatty acids (PUFA) if oil is the main component.

4.4.4. Hydrogenated Fats:

Hydrogenated fats are fully saturated and possess high malleability. They possess a broad spectrum of plasticity and can undergo processing to acquire a flavour that is devoid of any distinct characteristics. Hydrogenated fats consist entirely of fat and possess a higher capacity for shortening compared to butter or margarine. They are frequently employed in baking to attain a flaky texture in baked goods.

4.4.5. Oils:

Oils are characterised by their high liquid-to-fat crystal ratio and unsaturated nature, which allows them to remain in a liquid state at ambient temperature. Protein platelets are covered by them, which results in the mechanical reduction of gluten strands and the regulation of gluten formation. Oils enhance the tenderness of baked goods, but they may compromise the flakiness of pastries since they lack the presence of sizable fat chunks needed to build layers.

4.5. FRYING

Frying with melted fat or oil is a popular culinary procedure due to its ability to rapidly transmit heat and reach greater temperatures than boiling or dry heat. Fats used for frying must possess the following characteristics: colorlessness, odorlessness, blandness, and a high smoke point.

4.5.1. Smoke point:

The smoke point refers to the specific temperature at which fat can be cooked under controlled circumstances without producing a continuous emission of blue smoke from its surface. Smoke indicates the conversion of free glycerol into acrolein, an irritant to the mucous membranes. Monoglycerides in hydrogenated shortenings and glycerides undergo hydrolysis more readily than triglycerides, as they have a lower smoke point. Consequently, it is not advisable to use them in frying oils. When the temperature of the fat surpasses its smoke point, it can potentially reach the flash point, which is the temperature at which tiny flames ignite in the oil. Afterwards, it reaches the fire point, where the oil sustains a fire. Cottonseed and peanut oil both have a high smoke point, specifically 444°F (229°C) and 446°F (230°C), respectively.

4.6. FAT HAS VARIOUS FUNCTIONS IN FOOD PREPARATION:

- Fats are essential for enhancing the flavour and texture of foods.
- Fats facilitate the process of leavening batters and dough's, hence enhancing their airy and spongy texture.

- Fats have a role in adding flakiness and tenderness to baked foods, making them more appealing.
- Fats serve as emulsifiers, aiding in the amalgamation of water and oil-based components in different food items.
- Fats are a barrier that prevents meals from sticking to cooking surfaces and presentation.

Fats have a role in providing satiety by helping to control hunger and inducing a sense of fullness. Edible oils, commonly found in margarines, spreads, dressings, retail bottled oils, and frying oils, comprise the main market sectors for oils. Soybean oil, extensively utilized in the United States, is the predominant vegetable oil employed in many goods. To address concerns related to fat consumption, several fat substitutes have been created to imitate the sensory characteristics of fats while providing lower calorie and cholesterol levels. While fats and oils play a crucial role in enhancing flavour and texture, it is advisable to take them in moderation as part of a well-balanced diet. Lipids, including triglycerides, phospholipids, and sterols, are essential for other physiological processes beyond their role in energy provision.

4.7. CONSEQUENCES FOR HEALTH:

Most cis-configured fatty acids are found in naturally occurring fats and oils. Trans fats are formed when some double bonds undergo hydrogenation reactions and change to the Trans configuration. Trans fats have been linked to negative health outcomes, including elevated low-density lipoprotein (LDL) cholesterol levels. To assist customers in making dietary decisions, detailed labelling of Trans fatty acid content on food labels and marketing has been legislated.

SELF-ASSESSMENT QUESTIONS

Short questions:

1. What are fats' primary functions in food preparation, and how do they contribute to the overall sensory experience of food?
2. Describe the structure and composition of glycerides, including monoglycerides, diglycerides, and triglycerides, and their roles in food science.
3. Explain the significance of phospholipids and sterols, including their roles in food processing and nutritional value.
4. How do factors such as crystal formation, polymorphism, and melting points influence the functional characteristics of fats and oils in food manufacturing?

5. Explain the significance of hydrogenation in modifying fats' physical characteristics and stability. What are some of the health concerns associated with Trans fatty acids produced during hydrogenation?

Fill in the blanks

1. Polyunsaturated fats, primarily derived from plants, are _____ at normal ambient temperature.
2. _____ has the highest concentration of monounsaturated fat among prominent examples, at 75%.
3. _____ is the main form of rancidity that impacts fats and oils. The formation of undesirable tastes characterizes it and smells due to lipid oxidation.
4. Fat substitutes made from fat, such as Olestra and _____, have an impressive calorie content.
5. Examples of protein-based fat replacers include Whey-based and _____.

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UNIT -5

WATER

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INTRODUCTION

Water is an essential solvent or dispersant that helps to create colloidal solutions by scattering bigger molecules and true solutions by dissolving smaller ones. It is essential for many chemical reactions and enzyme-mediated processes, such as the hydrolysis of substances like sugars, and it catalyzes the ionization of acids and bases. In addition, water is a powerful cleanser and a medium for temperature regulation and heat exchange.

Water is the most important diluent of food solids. Water in foods has several effects on physical properties, food behavior in processing, microbial growth, stability, palatability, and phase transitions. The importance of water in foods is due to its presence in almost all foods, the dominance of water as a food component, and the physical properties and peculiarities of water in comparison with other food components.

The phase behavior of water as such is extraordinary. Water has fairly high melting and boiling temperatures as well as high latent heats of first-order transitions. In foods with high water contents the phase behavior of water is fairly similar to, although different from, that of pure water. Ice formation and separation of water from food solids occur below 0°C and boiling of water occurs at temperatures close to 100°C. The phase behavior of water and its thermodynamic characteristics govern and define processing conditions that are often necessary for food preservation by dehydration and freezing. Removal of water affects the phase behavior of remaining concentrated solids that begin to govern the physical state and transitions as water content is reduced. However, it should be noticed that the phase behavior of lipids defines the physical state of fats and oils and their mixtures.

LEARNING OUTCOMES

After studying this unit, you will be able to:

- ✓ To explain the thermal properties of water and their importance in cooking.
- ✓ To understand water activity and its role in food preservation.

5.1 CHEMISTRY OF WATER

The molecular formula of water, H_2O , highlights the strong covalent bonds that connect two hydrogen atoms with one oxygen atom. In liquid water and ice, the oxygen atom is positioned at the core of a tetrahedron. In liquid water, the bond angle formed by the oxygen atom is 105° , while in ice, the angle is slightly bigger at 109.6° . The bonds possess polarity and demonstrate a 40% partial ionic nature. As a result, the electrons in the outer shell are unequally distributed, with oxygen exerting a stronger attraction on them.

This causes oxygen to acquire a slight negative charge, whereas hydrogen acquires a slight positive charge. The presence of polarity allows for the creation of hydrogen bonds. Hydrogen bonds, weaker than covalent or ionic interactions, play an important role due to their high occurrence.

Due to the V-shaped structure of water molecules, each molecule can form a maximum of four hydrogen bonds with adjacent molecules. While a single hydrogen atom can form only one bond, the oxygen atom can establish two bonds, leading to the creation of a dynamic three-dimensional lattice structure in ice. Both ice and liquid water demonstrate hydrogen bonding, although liquid water displays a range of organized structures as the bonds continuously break and rejoin. The larger coordination number in liquid water results from molecules being able to pack more closely due to the smaller bond angle compared to ice.

Temperature impacts the mean separation between water molecules, hence influencing density. As the temperature increases, the molecules acquire more kinetic energy, causing them to move apart and reducing their density. Nevertheless, the coordination number has a more significant influence.

5.2 SPECIFIC HEAT AND LATENT HEAT OF WATER

When heat is applied to ice, its temperature increases in direct proportion to the quantity of heat provided.

5.2.1. Water's specific heat:

The specific heat of water, defined as the energy needed to increase the temperature of 1 gram of water by 1°C , remains consistent regardless of whether water or ice is being heated. A substance's high specific heat is due to the presence of hydrogen bonds. Specifically, it is about 1 calorie per gram per degree Celsius ($1 \text{ cal/g}^\circ\text{C}$). Therefore, it requires 100 calories of energy to increase the temperature of 1 gram of water from 0°C to 100°C .

Phase transition refers to the change in the physical state of a substance, such as the transition from ice to water. When the ice temperature reaches 0°C, an extra amount of energy is required to disrupt the hydrogen bonds and facilitate the transformation of ice into its liquid state.

5.2.2. The latent heat of fusion

It refers to the amount of energy, specifically around 80 calories per gram, needed to transition from one phase to another. Once the ice reaches 0°C, additional energy is needed to break the hydrogen bonds and transition the ice into its liquid form. During this phase change, there is no change in temperature until all the ice has converted into liquid. The energy required for this phase transition is known as the latent heat of fusion, approximately 80 calories per gram. Hence, 1 gram of ice at its freezing point absorbs around 80 calories as it transforms into liquid water.

5.2.3. The latent heat of vaporization

It is the energy needed to turn 1 gram of water into vapors at 100°C, which is approximately 540 calories per gram. Therefore, when water reaches its boiling point, it takes around 540 calories to convert 1 gram of water into steam.

5.3 WATER AS A DISPERSING MEDIUM

Water serves as a dispersion medium for dissolved compounds, resulting in the formation of genuine solutions. Based on the characteristics of the dissolved components, the solutions can be classified as either ionic or molecular. An ionic solution is a solution that contains ions, which are charged particles.

Ionic solutions are formed by substances that undergo ionisation in water, such as salts, acids, or bases. For example, when sodium chloride (NaCl) is dissolved in water, it breaks down into sodium (Na⁺) and chloride (Cl⁻) ions through dissociation. The water molecules envelop each ion, causing disruption to the ionic connections and enabling the ions to travel autonomously. Normally, every ion is surrounded by approximately six water molecules, forming a hydrated state.

5.3.1. Variables Influencing Solubility

The solubility of water compounds, particularly those involving hydrogen-bond interchange, escalates as the temperature increases. Applying heat causes the hydrogen bonds to break, decreasing the force of attraction between water and sucrose molecules. This makes it easier for water to interact with sucrose and form a solution. As a result, sucrose has a considerably higher solubility in hot water than in cold water.

5.3.2. Boiling point elevation

Solutes elevate water's boiling point. The solubility of sucrose significantly increases as the temperature rises, especially at 100°C, the boiling point of pure water. This phenomenon enables the estimation of sucrose concentration by measuring the boiling point of a solution containing sucrose. This is especially crucial in the confectionary and pectin jelly manufacturing processes.

5.4 WATER ACTIVITY

The ratio of the vapour pressure of water in a solution (P_s) to the vapour pressure of pure water (P_w) is known as water activity (A_w), and it is an important component in food preservation. Keeping a proper A_w is crucial for several reasons. For example, living tissues require enough water to maintain turgor. However, high A_w conditions also favor microbes like mold, bacteria, and yeast, which increases the risk of spoiling. Consequently, preservation methods consider the food's water activity to regulate microbial development.

5.5 ROLE OF WATER IN FOOD PRESERVATION AND SHELF LIFE OF FOOD

Two commonly used food preservation methods, drying and freezing, aim to lower the amount of water available and increase shelf life. Since water content directly impacts shelf life and consumer preference, controlling it is essential to sustaining food quality. For example, some dishes taste better when they're crispy or dry. By reducing the amount of water available to harmful or spoiling germs, freezing and drying successfully increase shelf life.

Food's texture and nutritional content are preserved through quick freezing, which reduces cellular damage to food. Preservatives can be added to food formulas in addition to freezing and drying to prevent mould or yeast growth. Humectants, which draw and hold moisture, are also utilised to keep food at the proper texture and moisture content. These additives greatly improve the quality and shelf life of preserved foods.

SELF-ASSESSMENT QUESTIONS

Short questions:

1. Why is water exclusion crucial to preserving the quality of certain food products?
2. Describe the significance of water in food processing techniques.
3. Explain the role of water as a solvent and dispersant in food science.

Multiple-Choice Questions:

1. **Which of the following statements accurately describes the impact of water on food texture?**
 - a) Water makes food softer and less crisp.
 - b) Water imparts crispness and turgor to fruits and vegetables.
 - c) Water does not affect food texture.
 - d) Water makes food more tender.
2. **What role does water play in the chemistry of food preservation?**
 - a) Water acts as a preservative.
 - b) Water facilitates freezing and drying processes.
 - c) Water accelerates bacterial growth.
 - d) Water has no role in food preservation.
3. **How does temperature influence the density of water?**
 - a) Increasing temperature increases density.
 - b) Increasing temperature decreases density.
 - c) Temperature does not affect water density.
 - d) Density remains constant regardless of temperature changes.
4. **What is the significance of water activity (A_w) in food preservation?**
 - a) Higher water activity inhibits microbial growth.

- b) Lower water activity promotes microbial growth.
- c) Water activity has no impact on microbial growth.
- d) Water activity regulates food texture.

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UNIT -6

MEAT, POULTRY, FISH AND DRIED BEANS

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INTRODUCTION

Meat is the consumable tissue of mammals and includes diverse animal products such as rabbits, poultry, and fish, in addition to conventional red and white meats like beef and mutton. This wide range of alternatives offers abundant opportunities for gastronomic exploration across various civilizations. Red meat includes cattle, veal, lamb, mutton, and hog, all produced from animals. On the other hand, white meat mainly refers to poultry. Seafood, derived from fish and game acquired from wild animals, further enhances the diverse range of meat consumption. In its original form, meat comprises three primary constituents: muscle, connective tissue, and adipose tissue (fat). The fat content differs, with lean slices having less adipose tissue than well-marbled ones. Meat softness is influenced by factors such as the precise location of the cut on the animal, the movement of the muscles, and changes that occur after the animal has died. These factors result in a range of textures in different pieces of meat.

LEARNING OUTCOMES

After studying this unit, you will be able to:

- ✓ To describe the nutritional composition and processing methods for animal and plant protein sources.

6.1. CHARACTERISTICS OF MEAT

6.1.1. Physical composition

Meat comprises three main types of tissues: muscle tissue, connective tissue, and adipose or fatty tissue. These tissues have essential functions and contribute to meat's overall composition and qualities.

6.1.2. Muscle tissue

Muscle tissue, commonly known as the lean tissue of meat, includes cardiac, skeletal, and smooth muscle types. Myofibrils within muscle cells consist of alternating thin and thick protein filaments called actin and myosin. These filaments are important for the contraction and relaxation of muscles. The myofibrils, enveloped by a delicate connective tissue layer termed endomysium, combine to create clusters called primary bundles. Secondary bundles are formed by many main bundles, with each secondary bundle being bordered by perimysium connective tissue. Individual skeletal muscles are separated by epimysium connective tissue. Within the muscular bundles are blood arteries and clusters of fat cells distributed throughout.

6.1.3. Connective tissue:

Connective tissue, which consists of protein and mucopolysaccharides, is found throughout the muscle and impacts the tenderness of the meat. Muscle bundles are surrounded by different connective tissues, including endomysium, perimysium, and epimysium. These tissues combine to attach muscles to bones and ligaments. Collagen, the primary protein found in connective tissue, adds strength and firmness but can be softened by using heat cooking, transforming into gelatin. Elastin, a protein with greater elasticity, and reticulin, present in younger animals, are less significant constituents of connective tissue.

6.1.4. Adipose Tissue

Fat exhibits variations in its content and appearance, contingent upon factors such as animal diet, age, and heredity. Adipose tissue envelops internal organs such as the heart and kidneys, whereas subcutaneous fat becomes seen upon skin removal. Intramuscular fat is located between muscles, while intramuscular fat, called marbling, enhances the juiciness and flavour of cooked meat.

6.1.5. Chemical composition

The chemical composition of meat displays considerable variety, with the ratio of water, protein, fat, and other components altering based on factors such as the

specific cut and trim. Here is a comprehensive analysis of each element: Meat's chemical makeup can significantly vary. It typically comprises 45–70% water, 15–20% protein, and a fat content ranging from 5% to 40%, influenced by factors like the cut and trimming. Except for the liver, which stores glycogen, meat contains negligible carbohydrate content.

6.1.6. Water

Water is a major meat component, comprising about 45-70% of its content. Lean meat derived from young animals exhibits a greater water content than mature animals, which possess more fat tissue. Water is found in muscle fibres and, to a lesser degree, in connective tissue.

6.1.7. Protein

Meat is abundant in high-quality or complete proteins, which consist of all the essential amino acids required for the synthesis of body proteins. Meat has three main categories of proteins:

- The essential components of muscle bundles are actin and myosin, which are proteins found in myofibrils.
- Proteins, such as collagen, and elastin, are found in connective tissue.
- Sarcoplasmic proteins include pigments such as hemoglobin and enzymes that are essential for oxygen transport and metabolic activities.
- Enzymes found in meat can exhibit proteolytic activity (degrading proteins), amylolytic activity (breaking down carbs), or lipolytic activity (breaking down lipids).

6.1.8. Fats

Meat can have a substantial variation in its fat content. While certain slices may have a fat content as low as 5%, others might contain as much as 40% fat. The saturation levels of fat composition vary. Specifically, subcutaneous fats tend to be more unsaturated than those around glandular organs. Adipose tissue is crucial to the animal's ability to withstand cold temperatures. It facilitates the transportation of fat-soluble vitamins A, D, E, and K. Additionally, it includes crucial fatty acids required to produce cellular membranes. Cholesterol is a substance found in different proportions in meat, with lean meat generally containing less cholesterol than fattier slices. It is found in all animal tissues.

6.1.9. Carbohydrates

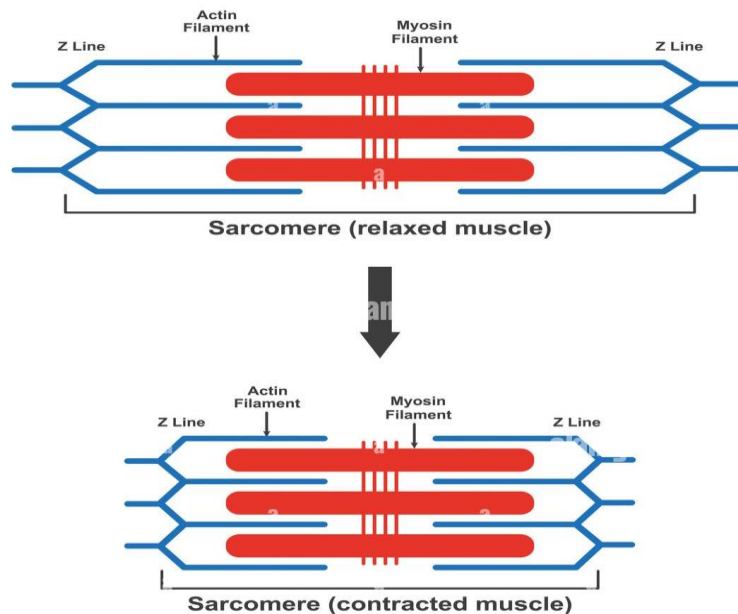
Animal tissues contain very small amounts of carbohydrates. Roughly 50% of this modest proportion is stored as glycogen in the liver, while the remaining portion is dispersed as glucose throughout the body, particularly in muscles and blood.

6.1.10. Vitamins

Meat is a rich source of water-soluble B-complex vitamins, which play a crucial role in many metabolic reactions, and fat-soluble vitamins A, D, E, and K, primarily stored in the liver. In addition, meat is rich in crucial elements, including iron (found in heme and myoglobin pigments), zinc, and phosphorus, which play a significant role in different physiological processes.

6.2. MUSCLE CONTRACTION IN LIVE ANIMALS

- Initiation of muscle contraction occurs when a nerve impulse prompts the release of calcium ions from the sarcoplasmic reticulum into the sarcoplasm, the jelly-like substance surrounding myofibril filaments.
- Calcium ions bind to specific sites on thin filaments, exposing active sites on actin molecules.
- Actin and myosin interact, forming actomyosin, with adenosine triphosphate (ATP) serving as the energy source for this process.
- Myosin contracts, pulling actin-containing filaments toward the sarcomere's centre.
- The actomyosin complex eventually breaks, and myosin forms new cross-links with different actin molecules, leading to further sarcomere shortening and muscle contraction.
- When the nerve impulse ceases, calcium ions are actively pumped out of the sarcoplasm, returning to the sarcoplasmic reticulum.
- Without calcium ions, actin and myosin cannot interact, causing the actomyosin complex to disassemble.
- As a result, the muscle relaxes and returns to its original elongated state.



6.2.1. Postmortem changes:

Before the process of slaughter, the muscular tissue in living animals exhibits a state of being supple and flexible. Following a specific timeframe after an animal is slaughtered, usually lasting from 6 to 24 hours, the muscles go through a process of becoming rigid and unyielding, which is referred to as rigor mortis, or "the stiffness of death." The stiffening occurs due to the reduced ability of the myofibril proteins, actin and myosin, to stretch, which is caused by the depletion of energy reserves and the lack of oxygen reaching the cells. Meat cooked while in a state of rigor mortis is very resilient. Consequently, most beef undergoes a maturing or conditioning procedure to regain its tender and flexible texture before cooking. The "resolution of rigour" is achieved by enzymatically breaking down the proteins that bind muscle fibres, hence reversing the stiffness. Nevertheless, it is crucial to acknowledge that this rigidity is transient.

After the killing process, a series of events occur within the muscular tissue, resulting in the beginning of rigor mortis. After death, aerobic respiration stops, blood circulation stops, and the muscles no longer receive oxygen, leading to anaerobic conditions. Glycolysis continues until either glycogen is exhausted or the pH drops to 5.5, causing the enzymes involved in glycolysis to lose their structure and cease the reaction. During this process, glycogen is converted into lactic acid and ATP. When glycolysis stops, the availability of ATP decreases quickly. In the

absence of ATP, calcium ions persist in the sarcoplasm, facilitating the formation of permanent cross-links between actin and myosin, resulting in muscular rigidity. In contrast to living animals, where actomyosin cross-links undergo continuous formation and dissociation during muscular contraction with the assistance of ATP, in rigor mortis, these cross-links remain intact and enhance the firmness of meat.

The severity of muscle rigidity during rigor mortis is determined by the level of actomyosin production, which is influenced by the interaction between thin and thick myofilaments. Increased overlap leads to greater output of actomyosin, resulting in stiffer muscles and tougher meat. To reduce the hardness of meat, measures are taken to decrease the production of actomyosin cross-links.

- By suspending the corpse after slaughter, the muscles are elongated, which decreases the shortening of sarcomeres and restricts the creation of actomyosin cross-links.
- To decrease fibre shortening, it is essential to control the temperature before rigour mortis onset within the range of 59°F to 68°F (15°C to 20°C). Deviation from this range of temperatures can result in heightened contraction or "cold shortening" and subsequently impact the creation of actomyosin cross-links.

Both procedures aim to reduce muscular contraction before rigour mortis, which decreases actomyosin cross-links and ultimately makes the meat softer.

6.2.2. Cuts of meat:

Meat is classified into primal or wholesale cuts, sub-primal cuts, and retail cuts. Primal or wholesale cuts are first taken from the animal and then further divided based on their tenderness and fat content. The sensitivity of a wound is determined by variables such as its placement on the creature's anatomy and the intensity of physical exertion in the associated muscle cluster. The tenderness of the meat is primarily defined by its susceptibility to tearing when bitten, considering factors such as the age of the cut and the cooking technique used. The primal cuts of beef, listed below in order of tenderness, encompass the most tender, moderately tender, and least tender cuts:

6.2.2.1. Extremely tender

Rib, Short loin, Sirloin, Foreshank, Tip

6.2.2.2. Moderately tender

Chuck, round, and brisket

6.2.2.3. *Least tender:*

Flank, Short plate

Subprimal cuts are obtained from primal cuts and are frequently subjected to additional processing before being sold at supermarket markets. If the meat is vacuum-packed, it may be sold as "beef-in-a-bag." If it is packaged in boxes, it may be sold as "boxed meat". These products are boneless and intended for retail sale. Subprimal cuts are categorized into distinct retail cuts, including roasts, steaks, and chops.

Retail cuts refer to the portions of meat that can be bought at retail markets. These cuts are derived from primal or subprimal cuts. They can be named either according to the original cut they come from or the bones they include.

Typically, cuts obtained from the neck, legs, and lower abdomen are less sensitive since these areas of the animal are subjected to more physical activity. Nevertheless, these reductions might be more agreeable by preparing them with moist heat to tenderize the connective tissue. In contrast, tender cuts are commonly prepared using dry heat methods.

The National Livestock and Meat Board, now known as the National Cattlemen's Beef Association, established standardized nomenclature and classification for retail cuts in the 1970s with the Uniform Retail Meat Identity Standards (URMIS). These requirements specify the inclusion of labels that indicate the specific type of meat, the primal cut it was derived from, and the name of the retail cut.

6.3 POULTRY

The poultry industry often experiences increased sales during periods when beef sales decline. All poultry products are subject to inspection under the Wholesome Poultry Products Act of 1968 and are graded based on quality, with grades ranging from US grade A to C. Factors such as conformation, fat content, and freedom from blemishes and broken bones influence the grading process. The inspection, labelling, and handling of poultry products are similar to meat products.

Dark meat from poultry comes from more exercised parts of the animal and contains higher levels of myoglobin, fat, iron, and zinc compared to white meat. However, removing the skin during cooking can reduce the fat content, as poultry cooked without the skin allows less fat to drip into the meat. Poultry with skin may contain slightly more cholesterol than an equal portion of lean beef. In addition to

whole birds, individual pieces such as breast meat, legs, and thighs are sold separately. Various processed poultry products, including lunch meats, ground turkey, and formed entrees like nuggets and patties, are also available in the American market. Poultry products must be adequately cooked to destroy Salmonella bacteria, a common pathogen associated with poultry.

6.4. FISH

Fish, including both finfish and shellfish, are commonly consumed and sourced from both marine and freshwater environments. The edible portion of fish is mostly composed of skeletal muscles. Fish has softer and flakier texture than mammals and fowl because it contains small muscle fibre bundles with thin layers of connective tissue.

Fish are categorised or grouped into different classes based on their characteristics and traits.

- Finfish, which are vertebrates possessing fins, possess a skeletal structure composed of bone and are enveloped by scales. These examples can be classified as either lean or fat: The following are examples of lean saltwater fish: cod, flounder, haddock, halibut, red snapper, and whiting.
- Lean freshwater fish include brook trout and yellow pike.
- Examples of fat saltwater fish include herring, mackerel, and salmon. Obese freshwater fish: catfish, lake trout, whitefish.
- Shellfish, which are invertebrates, can be classified as either crustaceans or molluscs. Some examples of shellfish include:
- Crustacea includes crab, crayfish, lobster, and shrimp. Molluscs include abalone, clams, mussels, oysters, and scallops.

The nutritional components of fish are similar to those of mammals and fowl.

Fat is a substance that can have different proportions and is mainly in liquid form, such as fish oil. It consists mainly of unsaturated fats, including omega-3 polyunsaturated fatty acids like Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fats are important for heart health.

The **protein** content consists of high-quality complete proteins, which include myofibril proteins such as actin and myosin, connective tissue proteins like collagen, and sarcoplasmic proteins such as enzymes and myoglobin.

Fish is naturally tender due to its lower amount of connective tissue compared to beef, resulting in a higher conversion of connective tissue to gelatin when cooked. The presence of flakes in cooked fish serves as an indication of its level of doneness. However, it is worth noting that restructured or "formed" fish, which is manufactured from minced fish, may not display flakes.

Surimi, a minced fish product often derived from pollack, is subjected to a washing procedure to eliminate oil, water-soluble compounds, and sarcoplasmic proteins, resulting in the retention of protein fibers. Subsequently, salt is introduced to dissolve the myofibril proteins, and other components are integrated to produce diverse goods such as imitation crabmeat.

6.5. DRIED BEANS AND PEAS (LEGUMES)

Legumes, such as beans, peas, and lentils, provide a wide variety of choices for the diet. Legumes, being plant-based protein sources, are classified as incomplete proteins due to their insufficient levels of essential amino acids. Conversely, animal-based foods such as meat, poultry, fish, milk, and eggs have complete proteins.

To get a well-rounded consumption of necessary amino acids, it is customary to blend two or more plant-based protein sources. For example, a vegetarian diet frequently incorporates legumes alongside nuts, seeds, or grains. Mutual supplementation, also referred to as the practice of taking complementary sources of incomplete proteins, entails consuming these sources within the same day rather than necessarily within the same meal.

Plant-based protein sources exhibit diverse amino acid compositions. Legumes, such as soybeans, black-eyed peas, and pinto beans, are a rich source of lysine. However, they are deficient in tryptophan and sulfur-containing amino acids.

Nuts and seeds, such as peanuts and sesame seeds, are a beneficial supply of tryptophan and sulfur-containing amino acids. However, they are not a significant source of lysine.

Examples of mutual supplementing can be observed in the combination of beans and rice, tofu, and veggies served on rice, black-eyed peas paired with cornbread, tofu, and cashews prepared as a stir-fry, or chickpeas accompanied by sesame seeds (hummus) or peanut butter on whole wheat bread.

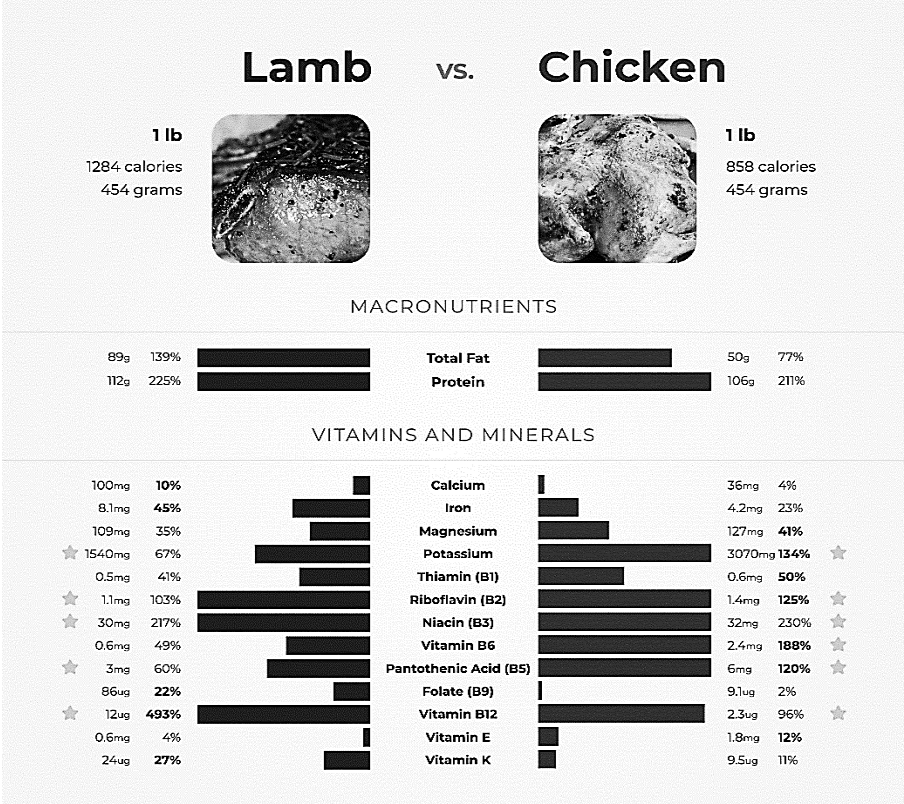
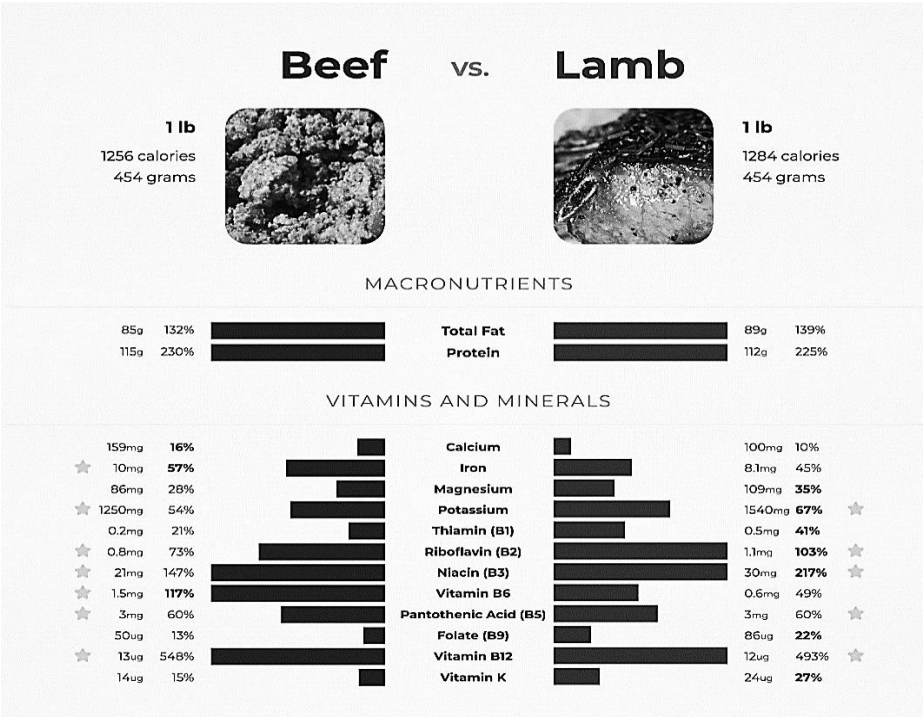
Legumes, which are the seeds of plants belonging to the Leguminosae family, exhibit a diverse range of shapes and colours, such as elongated, flattened, spherical, or kidney-shaped. Some common examples of legumes include kidney beans, soybeans, string beans (also known as snap beans or green beans), carob pods, and lentils. Peanuts, despite their name, are legumes rather than genuine nuts, and they mature beneath the ground. By cooking beans, the starch in them undergoes gelatinization, resulting in a soft texture and enhanced taste. Cooking also causes the protein to coagulate, thereby enhancing its digestibility.

Certain individuals may get gastrointestinal pain or flatulence as a result of ingesting legumes. To facilitate digestion, an enzyme obtained from Niger can be included in legume-based diets.

Soybeans, a prevalent legume, undergo frequent processing to produce a range of goods including soybean oil, tofu, frozen treats, soy flour, and textured vegetable protein (TVP). These goods offer substitutes for proteins derived from animals and are utilised in many culinary contexts, ranging from cooking oils to meat alternatives. Fermented soybean products such as soy sauce, miso, and tempeh provide distinctive tastes and nutritional advantages. In addition, soy protein concentrates and isolates are considered high-quality protein sources commonly employed in many food products.

6.6. NUTRITIVE VALUE OF POULTRY, FISH AND MEAT:

Understanding the nutritional value of meats, poultry, and fish is crucial in comprehending their significance in a well-balanced diet. Figures display the calorie, lipid, saturated fat, cholesterol, salt, protein, and iron content of beef and lamb. Meats are abundant in complete protein, vital B vitamins (particularly B12, exclusively found in animal products), and minerals such as iron and zinc. Moreover, seafood provides a diverse range of essential nutrients such as omega-3 fatty acids, vitamin D, and iodine. Soybeans, renowned for their antioxidant characteristics and having saponins with promising health advantages, have garnered attention for their contribution to cardiovascular well-being. In 1999, the FDA made a health claim stating that ingesting a minimum of 25 grams of soy protein per day, in addition to following a diet low in fat and cholesterol, could potentially lower the chances of developing coronary heart disease.



SELF-ASSESSMENT QUESTIONS
EXERCISE QUESTIONS FOR REVIEW

Short Questions:

1. What are the three main types of tissues found in meat?
2. Describe the structure of muscle tissue and its components.
3. What role does connective tissue play in meat, and how does it affect tenderness?
4. Explain the significance of adipose tissue in meat and its impact on flavour and tenderness.
5. What is rigor mortis, and how does it affect the tenderness of meat?

b) Fill in the blanks

1. Muscle tissue, _____, and adipose tissue are the three main types of tissues found in meat.
2. _____, the distribution of fat within muscle tissue, is prized for its contribution to flavour and tenderness.
3. Aerobic respiration produces _____, the energy source for muscle contraction, by fully breaking down glucose.
4. _____, on the other hand, provides quick energy during high-intensity muscle activity but is less efficient than aerobic respiration.
5. Legumes, such as soybeans, black-eyed peas, and pinto beans, are a rich source of _____.

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UNIT -7

MILK AND MILK PRODUCTS

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INTRODUCTION

Milk is the main source of nourishment for young mammals, secreted by the mammary glands of female mammals. It consists of a mixture of lipids and high-grade protein dissolved in water, coupled with lactose (a carbohydrate), vitamins, and minerals. This debate specifically centre around cow milk and its derivatives, although it is worth noting that milk and its products can also be obtained from other animals, such as goats and sheep.

Although fluid milk has a high water content, it can be condensed to create goods such as evaporated milk and cheese. It has various culinary applications worldwide, such as being consumed as a beverage, used in cheese-making, utilized in yoghurt manufacture, and added to soups and sauces.

According to regulations, milk and its products must have specific amounts of total milk solids (all components of milk except water) and milk solids, not fat (MSNF), without including the fat content. The butterfat content of milk determines whether it is classified and sold as whole milk or with reduced fat percentages such as 2%, 1%, 1/2%, or fat-free. Milk is subjected to many processing methods, including culturing, drying, fortification, homogenization, and pasteurisation, to create a diverse range of products that have unique flavours, textures, nutritional compositions, and durations of shelf life.

LEARNING OUTCOMES

After studying this unit, you will be able to:

- ✓ To understand the composition and processing of milk.
- ✓ To explain the various types of milk and their culinary applications.

7.1. COMPOSITION OF MILK

The content of milk might vary depending on factors such as the breed of the cow, the time of lactation, and the feeding methods. Due to its high nutritional content and ability to be used in a variety of ways, it is a valuable addition to the diet of different people.

Water:

Water is the main constituent of milk, making up around 87-88% of its makeup. Dehydrating milk products increases their longevity.

Carbohydrate:

Found in the liquid phase of milk at around 5% concentration, primarily as lactose. Lactose exhibits limited solubility and has the propensity to precipitate from a solution. During bacterial fermentation and cheese ageing, it undergoes conversion into lactic acid.

Fat:

Fat makes up approximately 3-4% of milk, mainly in the form of butterfat. Whole milk has elevated fat content, but reduced fat and skim milk have lower quantities. Creaming causes fat globules to float to the surface, whereas homogenization ensures that fat is equally dispersed. Milk fat consists of triglycerides, cholesterol, and phospholipids, with triglycerides being the main component (95%) and having different fatty acid constituents.

Protein:

Protein constitutes 3-4% of the content of milk, with casein being the primary protein, accounting for around 80% of the total milk protein. Casein undergoes aggregation at a pH of 4.6, forming stable spherical structures known as micelles. Whey proteins provide approximately 20% of the total protein content in milk and possess a higher hydration level. Additional protein constituents comprise lactalbumin, lactoglobulin, and enzymes such as lipase, protease, and alkaline phosphatase.

Vitamins:

Milk naturally contains water-soluble and fat-soluble vitamins, including riboflavin (B2) and vitamin A, in the fat component. Vitamin D is frequently added to whole milk as a fortification measure. Minerals such as calcium and phosphorus are

included in the composition at a concentration of around 1%. Calcium is present as calcium caseinate, while phosphorus is present as calcium phosphate. Included minerals include chloride, magnesium, potassium, sodium, and sulfur.

Component	Cow milk		Sheep milk	
	Amount	%	Amount	%
Total energy (kJ)	1649.3	-	2140.4	-
Fat (g)	21.3	3.3	33.4	5.1
Protein (g)	19.4	3.0	29.9	4.6
Lactose (g)	33.3	5.1	24.9	3.8
Total solids (g)	79.0	12.2	91.7	14.1
Solids non-fat (g)	57.7	8.9	60.3	9.3

Milk classification:

- The solution consists of lactose (sugar), water-soluble vitamins such as thiamin and riboflavin, and mineral salts including calcium phosphate, citrates, chloride, magnesium, potassium, and sodium.
- Colloidal dispersion, often known as a sol, refers to a mixture in which solid particles are dispersed in a liquid or gas medium. Comprises casein, whey proteins, calcium phosphate, magnesium phosphate, and citrates.
- An emulsion refers to the state in which fat globules are evenly dispersed and suspended inside the aqueous phase, or serum, of milk. The milk fat globule membrane, consisting mainly of protein and phospholipids, encloses the fat globules and prevents them from merging.

7.2. SANITATION AND GRADING OF MILK

Milk is classified as a potentially dangerous food because its abundant water content and nutrient makeup create favorable conditions for bacterial proliferation. To uphold safety and ensure high standards of quality:

- Raw milk must be quickly cooled to 40°F (4°C) or lower within 2 hours of being milked to prevent the formation of germs.
- Appropriate refrigeration guarantees that ordinary milk can be stored for 14 days, whereas ultra-pasteurized milk products can be stored for up to 45 days.
- Ensuring hygienic conditions throughout the production, processing, and distribution process is crucial to prevent harmful germs and preserve the quality of the product.
- Due to pasteurization, which effectively eliminates microorganisms, the incidence of diseases previously transmitted by unpasteurized milk, such as diphtheria, salmonellosis, typhoid fever, TB, and undulant fever, has significantly decreased.
- Regulations imposed by entities such as the USDA and state agriculture departments guarantee milk safety and quality in interstate and intrastate trade.

Milk is graded by bacterial counts, and Grade "A" milk adheres to strict criteria for fluid milk intake. Grades "B" and "C" are also present, indicating larger bacteria levels but still within the acceptable safety range. Dried milk is classified as US Extra and US Standard. USDA grades are available for all inspected milk on a voluntary fee-for-service basis.

7.3. FLAVOUR OF MILK

The flavour of milk is defined by its mild and subtle sweetness, as well as a distinctive texture that is attributable to its components:

Emulsified fat: Contributes to the smooth and velvety consistency.

Protein: Colloidally dispersed proteins contribute to the viscosity and texture of a substance.

Lactose: Contributes to the taste of sweetness.

Milk salts: Enhance the overall flavour character.

The aroma of fresh milk is attributed to the presence of chemicals such as acetone, acetaldehyde, methyl ketones, and short-chain fatty acids.

7.4 MILK PROCESSING

Pasteurization:

Pasteurization refers to the process of heating a substance, typically a liquid, to a specific temperature to destroy harmful microorganisms and extend its shelf life. Pasteurization, as defined by the FDA, is the process of heating dairy ingredients to precise temperatures and maintaining them at those temperatures for specific periods. The purpose of pasteurization is to eliminate harmful bacteria, yeasts, moulds, and a substantial amount of non-harmful bacteria. This method mitigates the likelihood of illnesses and prolongs the storage duration of milk.

Typical techniques comprise:

- The Low-Temperature Longer Time (LTLT) pasteurization method involves heating the substance to a temperature of 145°F (63°C) for 30 minutes or longer.
- High-temperature short-time (HTST) pasteurization involves quickly heating a substance to a temperature of 161°F (72°C) and maintaining it at that temperature for 15 seconds.
- Ultra-high temperature (UHT) pasteurization refers to the process of sterilizing food or beverages at temperatures between 280°F and 302°F (138°C to 150°C) for a duration of 2 to 6 seconds.

Pasteurization is mandatory for all Grade A fluid milk and milk products that are intended for interstate commerce and retail sales. It guarantees adherence to safety regulations and mitigates the spread of diseases like tuberculosis and Q fever. The verification of sufficient pasteurization involves checking for the lack of specific enzymes, such as alkaline phosphatase, which is naturally found in milk but gets destroyed at pasteurization temperatures. Enzyme tests are performed to verify the adequacy of pasteurization. Sterilization, also known as ultra-pasteurization, involves subjecting the product to elevated temperatures for a shorter period. Utilizing UHT processing, in conjunction with pre-sterilized containers in a sterile environment, effectively inhibits the growth of spoilage or pathogenic bacteria in the milk. Milk subjected to this process can be securely preserved for prolonged durations, such as 3 months or more, without refrigeration. Pasteurization is an essential process that guarantees the safety and prolonged shelf life of milk and milk products.

Homogenization:

Homogenization refers to the process of making something uniform or consistent throughout. Homogenization is an essential step in dairy production that aims to

provide a consistent composition in milk by preventing the separation of cream and improving the sensory and textural qualities.

The main purpose of homogenization is to reduce the size of fat globules in milk, which helps to distribute the fat throughout the milk uniformly. This eliminates the need for consumers to shake the container before using it. Homogenization mechanically reduces the size of fat globules from around 18 μm to less than 2 μm , resulting in a considerable decrease in their size. This procedure entails the utilization of a homogenizer to force milk through tiny mesh openings at a high pressure, usually ranging from 2000 to 2500 psi.

Attributes of Homogenized Milk:

- Homogenized milk ensures a uniform composition, preventing the cream from separating and rising to the top of the container.
- The more even distribution of fat particles causes greater absorption and reflection of light, resulting in whiter milk.
- Homogenized milk has a creamier texture due to a larger quantity of smaller fat particles, which results in a more viscous and creamy consistency.
- Homogenized milk may have a slightly diminished flavour profile in comparison to non-homogenized milk, owing to the presence of smaller fat particles.
- Homogenization can disrupt the membranes of fat globules, decreasing the stability of fat in milk.
- When exposed to sunlight or fluorescent light, homogenized milk may exhibit reduced stability to light and increased vulnerability to flavour degradation. To reduce the impact of this issue, milk is frequently packaged in paperboard cartons or opaque plastic bottles.
- Homogenization can be performed before or after pasteurization, executed expeditiously to uphold quality and regulate bacterial proliferation. In general, homogenization is crucial for improving milk products' sensory characteristics and shelf life.

Fortification:

Fortification is a vital process in dairy production aimed at enhancing the nutritional value of milk by adding specific vitamins and nutrients.

Adding fat-soluble vitamins A and D to whole milk is optional. While it's not required, many producers fortify whole milk to enhance its nutritional content. In contrast, low-fat milk, nonfat milk, and low-fat chocolate milk must be fortified

with specific levels of vitamins A and D. Typically, this fortification is done before pasteurization to ensure uniform distribution throughout the product. It's required for milk subjected to interstate commerce.

The fortification standards mandate 2000 international units (IU) or 140 retinol equivalents (RE) of vitamin A per quart for low-fat and nonfat milk. For vitamin D, 400 IU per quart is recommended, although fortification with vitamin D is optional. Evaporated milk must also be fortified to ensure adequate levels of essential vitamins.

Low-fat milk may add nonfat milk solids (MSNF) to increase viscosity, improve appearance, and enhance nutritive value. This addition increases the MSNF content to 10%, compared to the usual 8.25%. Products with this addition are labelled "protein-fortified" or "fortified with protein."

Bleaching:

Bleaching is a process used to remove carotenoid or chlorophyll pigments from milk, which may be desirable for certain applications. The FDA permits using benzoyl peroxide or a blend of benzoyl peroxide with potassium alum, calcium sulfate, or magnesium carbonate as bleaching agents in milk. The concentration of benzoyl peroxide must not exceed 0.002% of the milk's weight. Additionally, the total weight of potassium alum, calcium sulfate, and magnesium carbonate, individually or combined, must not exceed six times the weight of benzoyl peroxide.

7.4. TYPES OF MILK

7.4.1. Fluid milk:

Milk, obtained from several animal sources, is commonly consumed globally. It can be derived from a variety of animals, such as goats, sheep, and cows. The white hue of milk results from light reflecting off of casein protein and calcium phosphate particles distributed in a colloid. Nevertheless, the presence of carotenoid pigments in animal feed might lead to the appearance of off-white shades. Non-fat skimmed milk may appear bluish because it lacks carotenoid pigments. The FDA regulates the fat content and proportion of milk solids-not-fat (MSNF) in fluid milk. Various milk varieties, such as whole, reduced-fat, low-fat, and nonfat, have different fat percentages and calorie contents.

7.4.2. Evaporated and concentrated milk:

Evaporated and condensed milk undergo processing to prolong their shelf life and

improve mobility. Evaporated milk undergoes a concentration process where it is subjected to evaporation in a vacuum chamber, which removes 60% of its water content. Subsequently, the substance is made uniform in composition, enriched with vitamins A and D, sealed in cans, and subjected to sterilisation using a pressure canner. The composition standards for whole evaporated milk need a minimum of 25% total milk solids and 7.5% milk fat. Nonfat evaporated milk, on the other hand, must have at least 20% milk solids and no more than 0.5% milk fat. Both variants are enriched with vitamins A and D.

7.4.3. Sweetened condensed milk:

Sweetened condensed milk is concentrated with the addition of sugar to increase its sweetness and improve its ability to be stored for longer periods. Sweetened condensed milk undergoes a process where about 60% of its water content is removed, resulting in a concentrated product. The end product contains sugar levels that range from 40-45%. The composition standards for whole sweetened condensed milk require a minimum milk fat content of 8% and a total milk solids content of 28%. On the other hand, nonfat sweetened condensed milk must have a milk fat content of no more than 0.5% and a total milk solids content of 24%.

7.4.4. Dried Milk:

Pasteurized nonfat milk is widely used to produce dried milk powder, which provides convenience, a longer shelf life, and variety. The production process for milk powder entails the reduction of milk's water content by two-thirds through condensation, followed by spray drying in a heated vacuum chamber. This procedure decreases the moisture levels to below 5%, thereby conserving the milk powder.

7.4.5. Cultured Milk and Fermentation:

Cultured milk products undergo fermentation by adding bacterial cultures, typically lactobacilli and streptococci, which induce chemical changes in milk solids. In the past, warm milk from various animals was preserved without refrigeration by adding a small milk culture from a preceding batch. This allowed for the fermentation process to occur naturally, preventing spoilage.

7.4.6. Cultured Milk Products:

Buttermilk: Traditionally, buttermilk was a by-product of churning cream into butter, but commercially, it's often made from low-fat or nonfat milk. Cultured buttermilk contains phospholipids and protein from the fat globule membrane, adding to its texture and flavour.

Sour Cream: Made from fresh, homogenized cream, sour cream undergoes a similar fermentation process as buttermilk, but with shorter fermentation times.

Yoghurt: Produced by culturing pasteurized milk with specific bacteria such as *L. bulgaricus* and *S. thermophilus*, yoghurt offers various fat content options and may contain added ingredients like nonfat dry milk or whey for texture and flavour enhancement.

Acidophilus Milk: Contains *Lactobacillus acidophilus* cultures, potentially aiding in lactose digestion and offering therapeutic benefits.

Kefir: A fermented milk product containing bacteria and yeast cultures, imparting a unique flavour and slight carbonation.

Cultured milk products, like yoghurt, contain probiotic bacteria such as *Lactobacillus* and *Bifidobacteria*, which offer potential health benefits, including immune stimulation and GI micro flora balance. Special milk products include low-sodium, lactose-reduced, calcium-fortified, and flavored milk. Non-dairy alternatives like rice and soy milk are also available, catering to lactose-intolerant individuals. Cultured milk products provide a diverse range of flavours, textures, and nutritional benefits, making them popular choices in various cuisines and dietary preferences.

7.5. OTHER DAIRY PRODUCTS:

1. Butter:

Butter is produced by churning pasteurized cream, which disrupts the membranes of fat globules, causing the fat to come together and the water to be released (forming buttermilk).

Other types of butter exist, such as sweet cream butter. This type of butter used to be manufactured from soured cream, but nowadays, it is made from sweet cream with the addition of bacterial cultures to enhance its flavour.

Butter and margarine blends are offered, with different fat contents and flavours. Margarine, also known as oleomargarine, is composed of a minimum of 80% fat and can be produced using water, milk, or milk derivatives, along with vitamins A and D.

2. Cream:

The cream is the fatty portion of whole milk extracted, typically containing at least 18% milk fat. Several types of cream available include light, light whipping, heavy, and half-and-

half cream mixed with nonfat milk. Aerosol cans containing pressurized whipping cream may include a variety of additions to enhance flavour and maintain stability.

3. Cheese:

Cheese is produced by coagulating milk proteins using enzymes like rennet or lactic acid and then undergoing additional treatment, such as ripening. Cheeses can be classified into different categories based on their moisture content, such as hard, soft, semisoft, and very hard cheeses.

Ripening is the process in which bacteria, yeast, or mold ferment the food, resulting in changes in its texture, flavour, aroma, and colour. Cheddar, mozzarella, Swiss, blue cheese, and Parmesan are some of the most prevalent cheese forms. Each has unique qualities and is made using specific processes. Processed cheese, cheese food, and cheese spread are produced by grinding and blending genuine cheese with emulsifiers, flavorings, and additives.

4. Synthetic Cheese:

Synthetic cheese is produced using vegetable oil and does not possess authentic cheese's taste and melting characteristics. Some examples of processed cheese products are Velveeta, a spreadable cheese made through pasteurization, and Cheese Whiz, a sauce made from pasteurized processed cheese.

5. Ice cream:

Ice cream is a cherished delicacy that has been enjoyed for ages, and its mass manufacture started in 1851 in Baltimore, Maryland. The process involves freezing a mixture that has been pasteurized and contains dairy products along with other substances. The ice cream mixture commonly comprises dairy components such as cream, milk, skim milk, sweet cream buttermilk, or sweetened condensed milk. Possible additions include caseinates, sugar, eggs, fruit, nuts, flavoring agents, emulsifiers, stabilizers, and water. Protracted freezing can lead to the formation of bigger ice crystals, which can impact the texture of the end product. Ice cream comprises a minimum of 10% milk fat and 10% milk solids-not-fat (MSNF). There are many types of ice cream, such as low-fat ice cream (formerly known as ice milk), which has less fat and more MSNF, and deluxe ice cream, which has more milk fat and less MSNF. Some frozen desserts may include milk and different amounts of milk fat or fat replacements.

6. Whey:

Whey, a secondary result of the process of manufacturing cheese, consists of albumins, globulins, lactose, water-soluble nutrients, and whey proteins. It is progressively employed in consumer items, such as drinks, frozen dairy desserts, baked foods, and as an emulsifier or protein source.

Whey protein concentrates (WPCS) and isolates (WPIS) are obtained from whey and used in various food items, such as yoghurt, coffee creamer, baby formula, and processed meats.

7.6. COOKING APPLICATIONS

Milk proteins may change after denaturation, which could result in coagulation or precipitation. The following are the impacts of heat, acid, enzymes, and salts on milk proteins:

1. Temperature:

Intense or elevated heat can cause structural changes of denaturation, coagulation, or curdling in milk proteins. To minimize excessive denaturation, it is advisable to use slow, low, or moderate heat, such as indirect heating over a water bath, while working with milk-based goods. Elevated temperatures and extended heating can disrupt fat emulsion, leading to the merging of fat globules. Elevated temperatures can cause the creation of coagulated substances at the bottom of the cooking vessel, resulting in burning or charring. As water evaporates, a layer of surface scum or film may develop. This layer can trap heat and potentially lead to a boil-over. Utilizing a pan lid or spreading grease can be a preventive measure for this issue.

2. Acid:

Acid, whether given to food or generated by microorganisms, can cause the coagulation of milk proteins by creating unstable casein proteins. Casein undergoes precipitation at a pH of around 4.6, but whey proteins remain unaffected. The use of white sauce can effectively regulate the occurrence of precipitation.

3. Enzymatic coagulation:

Enzymes from different sources, such as animals, plants, or microorganisms, can induce coagulation and curd formation in milk. Rennin, often known as rennet, is the predominant enzyme utilized in cheese or ice cream manufacturing. It necessitates a mildly acidic milieu and operates most effectively within particular

temperature ranges. Rennin coagulation sequesters calcium in the curd, in contrast to acid coagulation, which releases calcium into the whey.

4. Coagulation of Polyphenolic Compounds:

Phenolic chemicals included in specific plant materials, including fruits, vegetables, tea, and coffee, can cause the coagulation of milk proteins. It is not advisable to add baking soda to milk mixtures to prevent curdling, as this would destroy vitamin C. Instead, one can utilise a gelatinized starch buffer at a low temperature.

5. Salt Coagulation:

The solubility of calcium and phosphorus salts in milk decreases when exposed to heat, potentially causing the coagulation of milk proteins. The presence of sodium-rich meals and salt additives in milk might lead to curdling. A gelatinized starch buffer inhibits unwanted precipitation, akin to acid-induced coagulation.

Safety and Quality of Milk

Milk is highly perishable due to its high water content, significant protein content, and nearly neutral pH (6.6), which provides ideal conditions for bacterial growth. While sanitation practices are crucial, understanding milk's care and safety is essential. Even non-dairy imitation "milk" may require refrigeration or freezing, similar to the dairy products they imitate.

Packaging typically includes a date indicating the carton's shelf life for retail sale. Despite the "sell-by-date," milk can remain fresh and usable for several days if proper precautions, suggested by the Dairy Council, are followed:

- Use appropriate containers to shield milk from sunlight, bright daylight, and strong fluorescent light to prevent off-flavour development and a decrease in riboflavin, ascorbic acid, and vitamin B6 content.
- Refrigerate milk promptly at temperatures of 45°F (7°C) or below after purchase. Keep milk containers sealed to prevent refrigerator absorption of another food flavour. Although absorbed flavours may alter the taste, the milk remains safe.
- Consume milk in the order purchased.

- Serve milk cold. Immediately return milk containers to the refrigerator to prevent bacterial growth. Even brief exposure to temperatures above 45°F (7°C) reduces shelf life for fluid and cultured milk products. Unused milk should never be returned to the original container.
- Store canned milk in a cool, dry place. Once opened, transfer it to a clean, opaque container and refrigerate.
- Serve UHT milk cold and refrigerate it after opening.

SELF-ASSESSMENT QUESTIONS/EXERCISE QUESTIONS FOR REVIEW

Short Questions:

1. Describe the process of pasteurization and its significance in dairy production.
2. How does homogenization affect the composition and characteristics of milk?
3. How are dried milk products produced, and what are their advantages?
4. Discuss the role of fermentation in cultured milk products and provide examples of such products.
5. How do heat, acid, enzymes, and salts affect milk proteins during cooking?

Multiple-choice questions

What is the main purpose of pasteurization in dairy production?

- a) Enhancing flavour
- b) Increasing fat content
- c) Extending shelf life and ensuring safety
- d) Improving texture

Which process mechanically reduces the size of fat globules in milk to prevent creaming?

- a) Fortification
- b) Sterilization
- c) Homogenization
- d) Fermentation

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UNIT -8

VEGETABLES AND FRUITS

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INTRODUCTION

Vegetables are consumable portions of plants, frequently served alongside or as a component of the primary dish. They are included in salads, soups, and various other cuisines. Vegetables can be subjected to several sorts of processing, including transformation into drinks, starches, or preservation through drying, pickling, or freezing methods. These adaptable components add distinct tastes, hues, and consistencies to meals and experience changes throughout preservation and preparation. Within vegetable crops, potatoes are notable for being extensively cultivated for human consumption, ranking second only to cereal crops such as wheat, rice, and corn.

In botanical terms, fruits are the fully developed ovaries of plants that contain seeds. This concept includes grains, legumes, nuts, seeds, and specific "vegetable fruits" such as cucumbers, olives, peppers, and tomatoes. However, in the context of cuisine, fruit often pertains to the succulent portion of a plant that is frequently taken on its own or presented as a sweet conclusion to a meal. Generally, fruits have more organic acids and sugar than vegetables.

Fruits and vegetables are crucial for a well-rounded diet due to their high nutritional content, which includes vitamins, minerals, fibre, and other advantageous substances. The continuing study reveals more dietary and medical advantages of consuming fruits and vegetables. According to the USDA, a 2000-calorie diet should include 2.5 cups of vegetables and 2 cups of fruit daily.

LEARNING OBJECTIVES

After studying this unit, you will be able to:

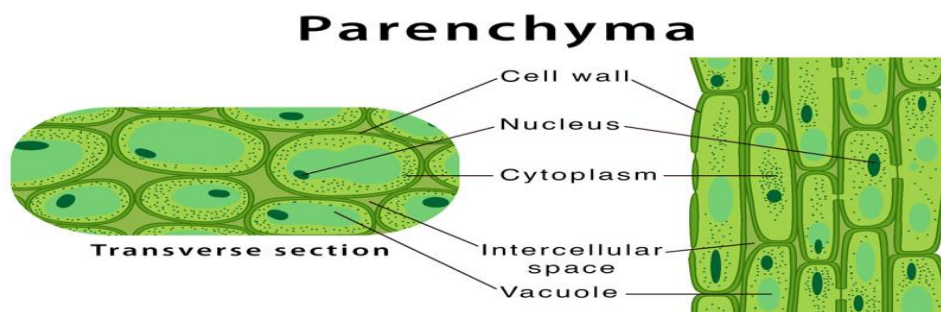
- ✓ To describe the structure, composition, and postharvest changes in fruits and vegetables.
- ✓ To understand enzymatic browning and methods to prevent it.

8.1. STRUCTURE AND COMPOSITION OF CELL TISSUE

To comprehend the characteristics and behaviour of fruits and vegetables, one must grasp the structure and makeup of their cellular tissue.

These cells share similarities in both their function and structure, which encompass:

- Dermal tissue is located on the external surface of leaves, young stems, roots, and flowers.
- Parenchyma tissue constitutes the largest portion of the plant and is responsible for the production and retention of carbohydrates. It is also the site for fundamental molecular processes such as photosynthesis.
- Complex tissue refers to a type of tissue that consists of multiple components or structures.
- Vascular tissue consists of the xylem and phloem. The xylem facilitates the upward movement of water from the roots to the leaves, whereas the phloem facilitates the downward movement of nutrients from the leaves to the roots.
- Supporting tissue, such as collenchyma and sclerenchyma, serves the purpose of providing structural support.
- Each cell is surrounded by the primary cell wall, mainly composed of cellulose, hemicellulose, and pectic compounds such as pectin. Mature plants may possess a secondary cell wall that is composed of lignin.
- The middle lamella, situated between neighboring cells outside the cell wall, functions as an adhesive material and comprises various substances such as pectic compounds, magnesium, calcium, water, and air gaps. It is essential for preserving the structural integrity of plant tissues.
- A vacuole is a cavity found within each parenchyma cell. Vacuoles exhibit size variations, ranging from substantial ones that can accommodate substantial quantities of water to smaller ones.
- The vacuoles contain cell sap, which consists of water-soluble substances like vitamins B and C, carbohydrates, inorganic salts, organic acids, sulfur compounds, and water-soluble colors.



8.1.1. Chemical composition

8.1.1.1. Carbohydrates:

Carbohydrates are the main constituent of plant material and make up the majority of its dry weight. They are synthesized through the process of photosynthesis, wherein the combination of water and carbon dioxide results in the production of carbohydrates and oxygen. Carbohydrates can be found in simple forms, such as monosaccharides (for example, glucose and fructose) and disaccharides (for example, sucrose), as well as in complicated forms, such as polysaccharides like cellulose and starch.

8.1.1.2. Protein:

The protein level in fruits and vegetables is often minimal, with legumes being the main source. Nevertheless, proteins can be derived from plants and employed in diverse food products. Plant-derived enzymes, such as papain from papaya, ficin from figs, and bromelain from pineapple, help to tenderize meats.

8.1.1.3. Fat:

The fat content in most fruits and vegetables is quite low, except for certain varieties such as avocados and olives. It is crucial for the initial development of plants.

8.1.1.4. Vitamins:

Fruits and vegetables are abundant in vitamins, specifically carotene (a precursor of vitamin A) and vitamin C. Water-soluble vitamins can be lost through the process of soaking and heating. Pre-freezing blanching preserves these vitamins by inactivating enzymes.

8.1.1.5. Minerals:

Fruits and vegetables provide essential minerals, including calcium, magnesium, and iron, to the diet. Calcium ions are used as a means to preserve the firmness of

canned vegetables. However, they are not added to vegetables such as spinach and peas because they can form strong bonds with oxalic acid and phytates, respectively.

8.1.1.6. Water:

Water is a constituent of plant cell walls and is a substantial component of plant tissues. It serves multiple functions in plant physiology and adds to the overall texture.

8.1.1.7. Phytochemicals:

Phytochemicals are plant molecules that are not essential for nutrition but may provide health advantages, such as preventing diseases and controlling cancer. Some examples of substances present in fruits and vegetables are carotenoids, flavonoids, sulfur-containing compounds, isoflavones, phytosterols, and phenols. They are now being studied to determine their potential impact on health.

8.2. Pigments and Effects of Additional Substances

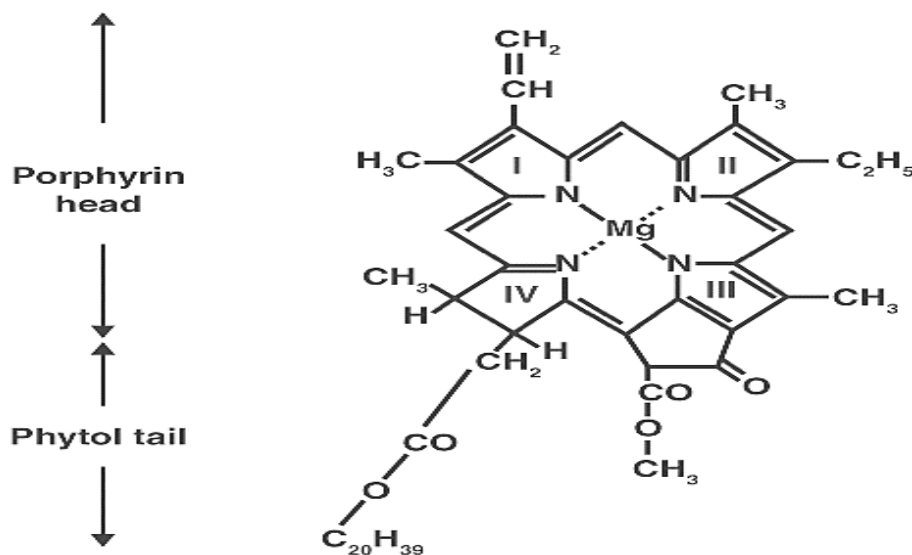
Plant pigments are essential for enhancing the visual attractiveness of vegetables and fruits to humans and attracting pollinators such as insects and birds. The pigments transform the maturation and preparation of uncooked vegetables or fruits. The four primary pigments present in plants are chlorophyll, carotenoids, anthocyanins, and anthoxanthins.

8.2.1. Chlorophyll:

Chlorophyll is a green pigment found in plants and algae that is responsible for their ability to convert sunlight into energy through the process of photosynthesis.

Chlorophyll, a green pigment, is located in the chloroplasts of plant cells and plays a crucial role in the process of photosynthesis. Chlorophyll is composed of a porphyrin ring containing magnesium at its core, encircled by four pyrrole groups. Extended storage, high cooking temperatures, alterations in pH levels, and the existence of minerals such as zinc and copper can cause the displacement of magnesium from the central location of chlorophyll, leading to alterations in colour. Green vegetables, when subjected to heat, release internal organic acids that displace magnesium and generate pheophytins, leading to the formation of pigments with grey-green or olive-green hues. Utensils made of copper and zinc can also lead to unwanted alterations in the colour of chlorophyll. In general, it is advisable to reduce cooking time to maintain the natural colour of vegetables and

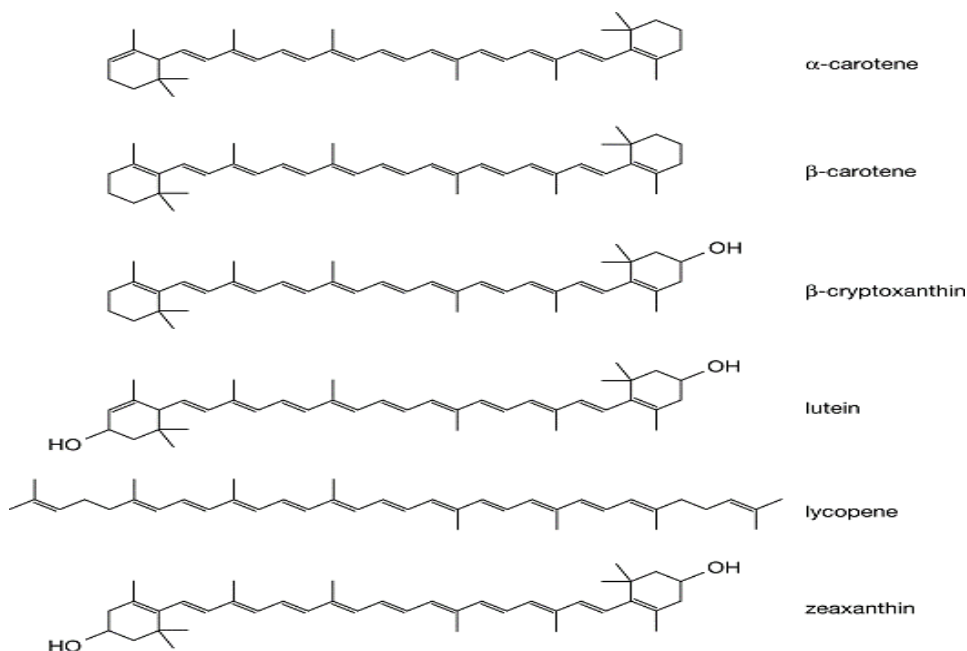
fruits. In addition, the inclusion of alkaline ingredients such as sodium bicarbonate can impact both the texture and nutritional content, despite their beneficial impact on colour.



8.2.2.Carotenoids:

Carotenoids are lipophilic pigments present in fruits and vegetables, which contribute to their hues of red, orange, and yellow. The compounds carotenes and xanthophylls are present in chloroplasts and chromoplasts, primarily in flowers, fruits such as tomatoes and peppers, and roots like carrots and sweet potatoes. Carotenes are a type of unsaturated hydrocarbon that gives meals their orange colour. Some examples are:

- Beta-carotene is naturally orange and has six-membered rings at both ends of its chain.
- Alpha-carotene is lighter in colour compared to beta-carotene because it has one less conjugated double bond.
- Lycopene is a compound that may be found in tomatoes and watermelon. It is a rich red-orange colour and contains two more double bonds compared to beta-carotene. Additionally, it has two open rings at either end.
- Xanthophylls are carotenoid derivatives that have a yellow-orange colour. They consist of carbon, hydrogen, and oxygen. Some examples of carotenoids are cryptoxanthin, found in maize, and lutein, found in green leaves.



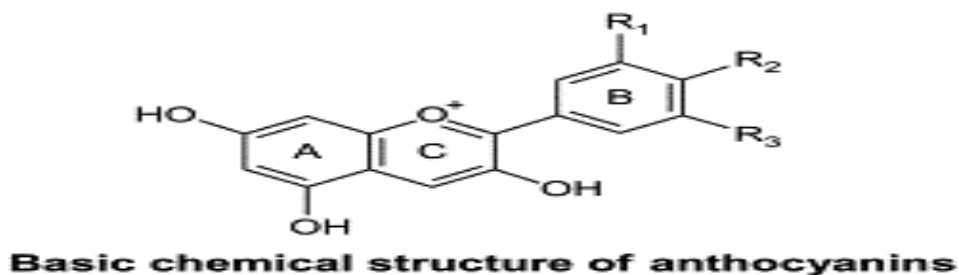
8.2.3. Anthocyanin:

Anthocyanin is a pigmented compound that imparts red, blue-red, blue, or purple colour to several fruits and vegetables, including blueberries, cherries, raspberries, red cabbage, red plums, and rhubarb. It is also found in the peels of radishes, red apples, red potatoes, grapes and eggplant. Anthocyanins are hydrophilic pigments that are classified as flavonoids and have a positively charged oxygen atom in the core part of their molecular structure.

Anthocyanin pigments exhibit varying reactions depending on the pH levels. Under acidic conditions, they have a distinctive red hue, whereas under alkaline conditions, they generate unattractive violet-blue or turquoise shades. For instance, the addition of alkaline leavens to mixed fruit juices or the inclusion of fruits in baked goods with alkaline leavens might lead to undesired alterations in colour.

The texture of foods containing anthocyanins is also influenced by pH levels. To enhance the colour of fruits and vegetables, it is advisable to add acids such as lemon juice or vinegar after the appropriate softening has taken place, as acids hinder the softening process. It is advisable to cook vegetables containing anthocyanin pigments with a lid to preserve the plant acids in the cooking water, which will enhance the colour.

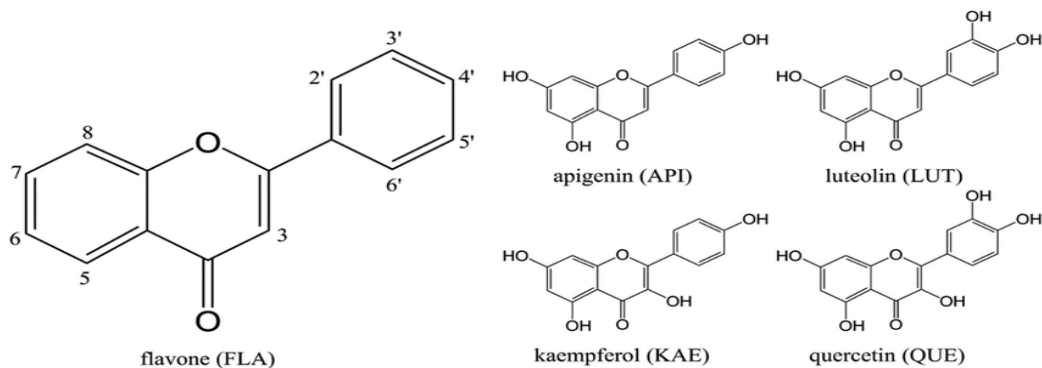
The presence of metals, such as iron from non-stainless steel preparation instruments, might alter the original purplish pigment, causing it to appear as a blue-green colour. Hence, food items that contain anthocyanin colouring are frequently preserved in lacquer-coated (enamel-lined) metal cans to avoid unwanted colour alterations resulting from the interaction with the metal.



8.2.4. Anthoxanthin:

Anthoxanthins are a flavonoid pigment similar to anthocyanin but less oxidized, with the oxygen on the central group uncharged. Anthoxanthins are white or pale yellowish, water-soluble pigments in a plant's cell sap. They are present in fruits such as apples and vegetables such as cauliflower, onions, and potatoes. Anthoxanthin pigment may turn into a brownish-grey colour with prolonged heat, especially in vegetables like potatoes with low organic acid content. Overcooking may cause some Anthoxanthins to change into anthocyanins, exhibiting a pinkish tinge.

Effect of pH: In acidic environments, anthoxanthins become lighter in colour, while in alkaline environments or the presence of iron salts, they may result in yellow or brown discoloration of white-cooked vegetables. Cooking in aluminum cookware can also cause similar discolorations.



8.2.5. Betalains:

Betalains are a minor group of pigments containing a nitrogen group in their molecular structure. They are not categorized as anthocyanins or anthoxanthins and differ in colour based on pH levels:

Betacyanines: These are red-colored pigments observed at a pH of 4–7.

Betaxanthines: Yellow-colored pigments seen at a pH above 10.

Betalaine: Betalaine below a pH of 4: They exhibit a violet colour.

Like anthocyanins, food products containing betalaine pigment are canned in lacquered cans to prevent colour changes caused by reactions with metals in the can.

8.2.6. Tannins:

Tannins, or tannic acid, are polyphenolic chemicals in several plant components, including bark, fruit, leaves, and roots. They provide both pigmentation and a tangy taste to dishes. Tannins exhibit a spectrum of hues, ranging from pale yellow to light brown, and are distinguished by their acidic properties that induce a puckering sensation in the mouth.

Health Benefits: Tannins present in beverages such as wine and tea are linked to antioxidant characteristics, which can potentially provide health advantages. Additionally, they have the ability to induce the precipitation of proteins, resulting in their solidification and separation from the solution. This feature is employed in operations such as wine clarifying. Tannins substantially impact the sensory perception of food and drinks and are linked to both culinary and health-related characteristics.

8.3. FLAVOUR COMPOUNDS

Flavour molecules are essential in defining the taste and scent of cooked vegetables. The chemicals encompass sulfur compounds present in allium and brassica vegetables, along with organic acids, concentrates, extracts, oils, spices, and herbs.

8.3.1. Allium:

Allium vegetables, including onions, garlic, leeks, and shallots, contain potent sulphur compounds that are responsible for their unique flavors. Allium vegetables demonstrate enzymatic activity when they are chopped or bruised, releasing chemicals responsible for their distinct flavours and fragrances. In order to reduce the intensity of the taste of cooked onions, it is advisable to boil them in a substantial quantity of water without a lid for a prolonged duration. On the other hand, cooking using oil yields the most concentrated flavour.

8.3.2.Brassica:

Brassica crops such as broccoli, cabbage, and cauliflower have chemicals that provide a potent taste when subjected to excessive cooking. To produce the best flavour in brassica vegetables, simmer them in a small amount of vigorously boiling water for a brief period. Make sure to cook them uncovered at first to allow volatile organic acids to escape.

8.3.3. Acids derived from organic compounds:

According to sources, fruits and vegetables contain organic acids including citric acid, malic acid, and tartaric acid, which are responsible for their tart or sour flavour. Fruits often contain a greater abundance of organic acids, but vegetables maintain a lower pH level that is less acidic.

8.3.4. Concentrates, extracts, oils, spices, and herbs:

These substances are utilized to impart clean and consistent flavours to food products, serving as substitutes for fresh or dehydrated veggies or to intensify existing flavours. Concentrates, extracts, oils, spices, and herbs are obtained from natural plants and can provide a diverse array of flavours and fragrances to foods. Herbs and spices are frequently utilized not only for their culinary value but also for their medicinal attributes, combining traditional and contemporary healthcare practices. Strategically incorporating these flavour components can significantly increase the taste and scent of cooked vegetables, providing a varied and gratifying culinary experience.

8.4. CLASSIFICATION OF VEGETABLES:

Vegetable classifications are used to categorize the edible components of plants, which might differ depending on geographical locations and cultural practices.

- Roots are the subterranean components of a plant that are usually abundant in nutrients and carbohydrates. Root vegetables include beetroot, carrot, jicama, parsnips, radish, rutabaga, sweet potato, turnip, and yam.
- Tubers are enlarged fleshy stems that grow underground and function as a storage organ for starch. Examples of tuberous plants are the Irish potato and the Jerusalem artichoke.
- Bulbs: Characteristics: Stems possessing a subterranean bulb serving as a nourishment storage organ. Examples of allium vegetables include garlic bulbs, leeks, onions, and shallots.
- Stems are a plant's vascular system, which contains a high amount of cellulose. Examples of vegetables include asparagus, celery, kohlrabi, and rhubarb.

- Leaves produce carbohydrates, including Brussels sprouts, cabbage, lettuce, parsley, and spinach. It also encompasses seaweed and leafy greens like beetroot, collards, kale, and mustard.
- Flowers are Clusters of flowers present on the stalk.

Examples of vegetables include artichokes, broccoli, and cauliflower.

- Fruits are defined as mature ovaries that contain seeds and are often delicious and luscious. Examples of fruits include apple, banana, berry, and orange. Additionally, there are vegetable fruits, including avocado, cucumber, eggplant, okra, olive, pepper, pumpkin, snap beans, squashes, and tomato.
- Seeds are located inside the fruit or pods of a plant.
- Dry beans, peas, and peanuts are examples of legumes that can be sprouted for ingestion. In the United States, although technically a grain, sweet corn can also be sprouted.

8.5. HARVESTING AND POSTHARVEST CHANGES

Harvesting at the ideal stage of maturity is crucial to get maximum flavor, texture, and nutritional value in crops. Immature fruits and vegetables may be preferable because they ripen more fully after being removed from the vine or plant.

Packaging the produce in cans immediately after harvesting, before transportation, can effectively preserve its freshness and quality. Following harvest, fruits and vegetables respire, releasing moisture, heat, and carbon dioxide. The peak respiration rates generally occur shortly before complete ripening. Climacteric fruits undergo ripening after harvesting, but non-climacteric fruits ripen before harvesting.

8.5.1. Controlling Light Exposure:

Exposing vegetables like onions or potatoes to natural or artificial light after they have been harvested might result in the development of unwanted substances such as green chlorophyll pigment and solanine. Selecting suitable packaging for transportation is essential to safeguard fruits and vegetables. Optimal storage conditions should be established to preserve moisture and prevent mould growth or decay of the stored items.

8.5.2. Ripening:

The ripening process in fruits and vegetables is a captivating phenomenon characterised by enzyme activity, hormonal fluctuations, and physical alterations. Although it may not be immediately noticeable, ripening involves internal changes

that eventually become apparent externally. For example, chlorophyll breakdown causes a colour shift, exposing carotenoid pigments during the ripening process of fruits. Concurrently, there is a rise in sugar concentration and a decline in acidity, which modifies the taste characteristics.

Despite being colourless and odourless, ethylene gas plays a crucial role in ripening. The release of this substance accelerates the softening of plant cell walls, speeding up the ripening process. Apples, bananas, and tomatoes are fruits and vegetables that inherently generate ethylene. Nevertheless, an overabundance of exposure to this gas can result in untimely ripening and decay. It is essential to store products that produce ethylene separately from those that do not need to ripen. In controlled circumstances, artificially generating ethylene gas through the combustion of hydrocarbons can facilitate the uniform ripening of fruits. An effective method for ripening fruits at home is to place unripened fruits in a paper bag, which will trap ethylene and speed up the ripening process. To mitigate the unfavorable consequences of ethylene, applying gibberellic acid can be employed to postpone the ripening process and uphold the state of firmness. This is particularly crucial for managing and transporting crops once harvested. Senescence, also known as over-ripening, leads to softening due to the conversion of intracellular protopectin into water-soluble pectin. It is possible to utilize edible waxes and treatments such as irradiation to prolong the period during which a product can be stored without spoiling.

Refrigeration can reduce harmful chemical reactions, while controlled environment storage and packing provide precise control over the ripening process by regulating levels of carbon dioxide (CO₂) and oxygen (O₂). Enzymes such as sucrose synthetase and pectinase are used as indicators of ripeness in specific types of produce, helping to assess their quality. To maintain the freshness and flavour of fruits and vegetables from the time they are harvested until they are consumed, it is crucial to have a comprehensive awareness of and the ability to manage the ripening process.

8.6. ENZYMATIC OXIDATIVE BROWNING

When fruits or vegetables are damaged or sliced while being prepared, they become vulnerable to enzymatic oxidative browning. This occurs when phenolic chemicals react with enzymes in the presence of oxygen, resulting in unwanted discoloration. An efficient approach to managing browning is to minimize the interaction between the substrate and oxygen. This can be accomplished by enveloping the food with

sugar syrup or a film wrap to impede the passage of oxygen. Moreover, using citric acid powder, ascorbic acid, or lemon juice in the incised area can help. When water is added to lemon juice, it supplies vitamin C and hinders enzyme activity because of its acidic pH.

Blanching fruits or vegetables before freezing is a customary procedure among home growers. Blanching eliminates the polyphenol oxidase enzyme, guaranteeing that the produce retains its quality in the freezer. This process is briefly submerging diced fruit or vegetable pieces in boiling water for a particular duration, which is determined by the volume and texture of the food.

8.7. FRUITS COOKING PRINCIPLES

The distinction between botanical and culinary definitions of fruits is intriguing. Botanically, fruits encompass a broader range of plant parts, including what are commonly considered vegetables in culinary contexts. The United States Supreme Court's 1893 ruling classified tomatoes as vegetables for tariff purposes, highlighting the disparity between botanical and culinary classifications.

Water loss can occur in fruit preparation, as seen when fresh-cut strawberries are sprinkled with sugar, leading to osmotic water loss and the release of red liquid. This effect and enzymatic oxidative browning can affect the appearance and texture of various fruits.

8.7.1. Fruits preparations:

Cooking fruits can be done in different ways, each yielding distinct outcomes:

Cooking in Water: When fruits are cooked in plain water, osmosis causes water to move into the tissues, resulting in plumpness. Pectins become soluble, making the fruit tenderer, while cellulose softens. However, the fruit loses its shape in this process.

Sugar Addition: Adding sugar to cooking water offers flavour and some preservation benefits. High sugar concentrations maintain fruit shape by drawing water out of the fruit through diffusion, interfering with pectin solubility, and dehydrating cellulose and hemicellulose. Early addition of sugar preserves fruit shape, while late addition results in softer, saucier textures, as seen in fruit sauces like applesauce.

Flavour Changes: Cooked fruits may taste blander due to water-soluble sugars and other molecules escaping. Adding sugar during cooking can enhance flavour.

8.7.2. Food Safety of Vegetables and Fruits

Although fruits and vegetables are typically deemed healthy, they can contain harmful bacteria that can lead to illness if necessary measures are not followed. Foodborne infections can be caused by cross-contamination, inappropriate handling, and storage methods.

Pathogenic microorganisms, including bacteria like Salmonella, E. coli 0157:H7, Campylobacter, Listeria, and others, have the potential to contaminate fruits and vegetables, resulting in foodborne illnesses.

8.7.3. Precautions

Prioritise cleansing ready-to-eat fresh vegetables before consuming them and swiftly storing them in a refrigerator. To prevent cross-contamination, it is important to minimise contact with other foods and adhere to standard hygiene protocols while handling and preparing food.

SELF-ASSESSMENT QUESTIONS

Short Questions:

1. What causes enzymatic oxidative browning in fruits and vegetables, and what methods can be used to prevent it?
2. How does cooking affect the texture, flavour, and nutritional value of vegetables and fruits?
3. What are the differences between fruit juices and juice drinks regarding their composition and labelling requirements?
4. How are vegetables incorporated into vegetarian dishes, and what considerations should be made for individuals following plant-based diets?

Multiple choice questions

What is the main function of the middle lamella in plant tissues?

- a) To provide structural support,
- b) To facilitate the upward movement of water,
- c) To serve as an adhesive material between neighboring cells,
- d) To store carbohydrates

Which of the following pigments is responsible for the green colour in plants?

- a) Anthocyanin
- b) Carotenoids
- c) Chlorophyll
- d) Anthoxanthin

What is the significance of tannins in fruits and vegetables?

- a) They provide a sweet taste.
- b) They enhance the colour of fruits and vegetables.
- c) They contribute to the astringent taste and texture.
- d) They help in ripening fruits.

What is the primary role of respiration in fruits and vegetables after they are harvested?

- a) To release heat and carbon dioxide
- b) To prevent ripening
- c) To reduce moisture content
- d) To increase acidity

Which of the following vegetables is an example of a tuber?

- a) Carrot
- b) Beetroot
- c) Potato
- d) Onion

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UNIT -9

FOOD EMULSIONS AND FOAMS

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INTRODUCTION

Emulsions include a wide range of convenience foods, including frozen sweets, meat products, margarine, and certain natural foods like milk and butter. Emulsions are either water distributed in oil or oil dispersed in water. Typically, these liquids do not blend, leading to the formation of distinct layers when they are combined. By forming an emulsion, the liquids are thoroughly blended to produce a unified layer with droplets of one liquid scattered throughout the other. The stability of food emulsions is essential since it prevents the separation of oil and water. Stability is usually attained by introducing an appropriate emulsifier; in certain cases, a stabilising chemical may also be required. Food foams, such as whipped egg whites, resemble emulsions, except that instead of two liquids, they contain a gas (often air or carbon dioxide) scattered in a liquid. The elements that affect the stability of emulsions are likewise relevant to foams. Ice cream and whipped cream are examples of meals that have a high level of complexity since they serve as both emulsions and foams at the same time.

LEARNING OBJECTIVES

After studying this unit, you will be able to:

- ✓ To explain the formation and stabilization of emulsions and foams.
- ✓ To understand the role of emulsifiers and foaming agents in food products.

9.1. EMULSIONS

An emulsion is a colloidal system consisting of immiscible liquids, where one liquid is spread as droplets within the other. The small liquid particles are known as the dispersed phase, while the liquid surrounding them is called the continuous phase. Food emulsions normally consist of two liquids, namely oil and water. An emulsion is an oil-in-water (o/w) emulsion when water is used as the continuous phase. Alternatively, when oil is the dominant phase, the emulsion is called a water-in-oil (w/o) emulsion. Oil-in-water emulsions are commonly found in salad dressings, mayonnaise, cake batter, and frozen desserts. On the other hand, butter, margarine, and certain icings are instances of water-in-oil emulsions. Emulsions are classified as colloidal systems because of their variable droplet size, which is normally around 1 μm but can vary significantly. Unlike colloidal dispersions with a solid dispersed phase, emulsions have a dispersed liquid phase.

9.1.1. Surface tension

To create an emulsion, it is necessary to compel two liquids that do not usually blend to mix with one another. One must consider the intermolecular forces acting on the liquid molecules to comprehend this process. The presence of powerful, cohesive forces between liquid molecules leads to substantial surface tension, which hinders the liquid's ability to spread easily. Surface tension is the measure of the force needed to separate molecules and increase a liquid's surface area or spread. The term "surface tension" is used when a gas surrounds the liquid surface, which is usually the case. However, when there is a boundary between two liquids, such as water and oil, the term "interfacial tension" is used. High surface or interfacial tension can create difficulties when trying to combine liquids or a liquid with a gas. This requires techniques to decrease surface tension in emulsion and foam generation processes.

9.1.2. Surfactant molecules

To reduce surface or interfacial tension, decreasing the cohesive forces among liquid molecules is essential, enabling their dispersion. Surfactants are introduced to accomplish this goal. Surfactant molecules tend to accumulate at the surface of a liquid because of their molecular structure. Usually, a portion of the molecule exhibits hydrophilic properties, meaning it has an affinity for water or polar characteristics. The hydrophobic portion has a low water affinity, causing it to situate itself as far as possible from the water. In contrast, the polar segment is strongly attracted to water but shows minimal attraction to oil. As a result, the molecule positions itself on the surface so that the polar part is submerged in water, and the non-polar part is exposed to air or oil.

Proteins display surface activity as a result of their hydrophilic and hydrophobic regions. The occurrence and size of these sections differ based on the precise arrangement of amino acids in each protein, with some proteins showing a higher tendency for being positioned on the surface.

In addition, spices such as dry mustard and paprika are used as surface-active agents since they tend to gather at the surface of the liquid rather than in its entirety.

9.1.3. Formation of Emulsion

An emulsion is formed by combining oil, water, and an emulsifier. Although there are different types of food emulsions, they all consist of these three essential components. To form an emulsion, it is crucial to evenly distribute either the oil or water phase into tiny droplets that remain uniformly dispersed inside the other liquid. This process requires energy and is usually carried out using a mixer or homogenizer. When oil and water are mixed, little droplets are formed, often made up of oil.

The emulsifier adheres to the surface of these recently created droplets, diminishing the tension between the interfaces and enabling the creation of more, smaller droplets. A decrease in the surface or interfacial tension between oil and water facilitates the fragmentation of one liquid into droplets, enabling the other liquid to flow around them more effortlessly.

Typically, the emulsifier determines which liquid becomes the continuous phase. Due to their preference for water, emulsifiers that easily mix with water generally decrease the tension between water and oil more than the tension between oil and water.

This promotes the creation of emulsions where oil is dispersed in water. In contrast, emulsifiers that have a higher ability to spread evenly in the oil phase generally form water-in-oil (w/o) emulsions.

Principles governing the creation of a stable emulsion of oil in water:

- Distribute the emulsifier evenly in the water-based phase.
- Apply oil to each liquid and decrease the interfacial tension using the emulsifier.
- Provide energy through the process of mixing or homogenization.
- Disperse the oil phase into small droplets that are enveloped by water.
- The emulsifier adheres to the surface of the recently formed oil droplets.
- Create microscopic droplets coated with an emulsifier on their surface.

- The oil's interfacial area experiences a substantial increase.
- The aqueous phase surrounds each oil droplet.
- The emulsion can thicken due to multiple small oil droplets enveloped by a thin, continuous phase.
- If the interfacial film is strong and resistant, the emulsion will maintain its stability.

9.2. EMULSIFIERS

Emulsifiers are required to absorb immiscible liquids, such as oil and water, at the interface.

- Decrease the interfacial tension of each liquid, making it easier for one liquid to spread over the other.
- Create a durable, unified, and flexible film at the interface.
- Inhibit or postpone the merging of the emulsion droplets.
- The reduction of interfacial tension facilitates the development of emulsions by minimizing the energy needed to disperse one liquid into droplets and disperse the other liquid around them. The production of a movie that hinders the coming together of substances promotes the stability of a mixture.

9.2.1. Natural Emulsifiers

Proteins are the most efficient emulsifiers as they undergo unfurling or denaturation and bind to the interface, creating a durable interfacial film. Proteins exhibit a proclivity to undergo unfolding, causing their hydrophobic regions to align with oil and their hydrophilic regions to align with water.

Caseins in milk also function as exceptional emulsifiers. They are vital in the production of homogenized milk and dairy desserts. Caseins in raw, untreated milk are organized into casein micelles. Electron micrographs have shown that entire micelles, along with individual protein molecules, are present on the surfaces of fat globules after homogenization. The stability of homogenized milk is attributed to these micelles rather than the individual protein molecules. Lecithin is widely recognized as an emulsifier, functioning as a surfactant that helps wetting and promotes blending substances, such as hot drink mixes. However, it usually does not autonomously create strong interfacial films and is not the preferred emulsifier unless combined with other emulsifiers or stabilizers.

9.2.2. Synthetic Emulsifiers and Surfactants

Synthetic emulsifiers, or surfactants, are chemical compounds that help stabilise and mix substances that normally separate, such as oil and water.

Most synthetic emulsifiers can be more precisely classified as surfactants due to their tiny molecular size compared to proteins. Their main function is to assist in dispersing fat rather than stabilizing emulsions. Surfactants, such as mono- and diglycerides, are included in shortenings and cake mixes to aid in the even distribution of the shortening. Cakes, as intricate combinations of fat droplets and air bubbles, are classified as emulsions and foams. Mono- and diglycerides aid in shortening dispersion into smaller particles, facilitating the inclusion of multiple air cells. This, in turn, increases the volume of the cake and leads to a more consistent texture in baked goods.

Glycerol monostearate is a prevalent monoglyceride utilized in the food industry. Esters can be formed by reacting acids with monoglycerides, producing a distinct category of surfactants. One example is **sodium stearoyl-2-lactylate**, which is commonly used in baked goods. There are two other types of synthetic surfactants, known as **SPANS** and **TWEENS**. SPANS are fatty acid esters of sorbitan, while TWEENS are fatty acid esters of polyoxyethylene sorbitan. Although all surfactants are amphiphilic, they display different levels of hydrophobic (lipophilic) and hydrophilic properties.

The quantification is determined using the hydrophilic/lipophilic balance (HLB) scale, which spans from 1 to 20. Surfactants with low HLB values (3–6) exhibit higher hydrophobic or lipophilic properties and are employed in creating water-in-oil (w/o) emulsions.

9.2.3. Examples of Emulsions

Mayonnaise is a persistent emulsion that remains stable even when handled normally. The essential components include oil (dispersed phase), vinegar (continuous phase), and egg yolk. Proteins in egg yolk are highly effective at preventing oil droplets from combining, thanks to their exceptional emulsifying properties. Mayonnaise generally consists of around 75% oil, which is present as stable droplets surrounded by a thin layer of water.

The composition of this substance is characterized by a higher concentration of the dispersed phase compared to the continuous phase. Mayonnaise is created by slowly adding small quantities of oil to a combination of vinegar and egg yolk while continually beating to produce droplets and form an emulsion. With the addition of oil, the formation of droplets is intensified, resulting in a significant augmentation of the surface area. The continuous phase envelops the oil droplets, forming a thin film. Because the droplets are closely packed and separated by a thin liquid phase,

their movement is hindered, forming a thick mayonnaise that may have a consistency firm enough to be sliced.

9.2.4. Factors Influencing Emulsion Stability

Various factors influence emulsions' stability, with the emulsifier playing a crucial role. Emulsifiers that can create stable films at the interface help maintain stable emulsions as long as there is enough emulsifier to cover the surface of all the droplets.

- Emulsion stability is also influenced by how storage and handling are carried out. Although certain emulsions are categorized as permanent, they possess intrinsic instability because they consist of two liquids that cannot mix, rendering them vulnerable to disruption in unfavorable circumstances.
- Temperature fluctuations also impact the stability of emulsions. Heating emulsions enhances the flow ability of oil droplets, increasing the chances of them merging. On the other hand, when emulsions are cooled to refrigerator temperatures, the oil droplets may solidify, potentially improving stability. Gums are frequently added to emulsions that are meant to be frozen to improve stability.
- Emulsion stability can be compromised by the presence of heat and intense agitation. For example, cream is transformed into butter by agitating a heated emulsion through a process called churning. This procedure causes the emulsion to break apart, causing the aqueous phase to separate and creating a water-in-oil emulsion where water droplets are scattered inside the butterfat.
- Emulsion stability is determined by several parameters, including the emulsifier's type and concentration, droplet size, pH, ionic strength, viscosity, the addition of stabilisers, and external conditions like temperature, storage, and handling procedures.

9.3. FOAMS, FOAM STABILITY, FOAM FORMATION

Foams are essential for determining the texture and volume of many food products, greatly influencing their attractiveness and consumer approval. They contribute to the volume and distinctive texture of things such as whipped cream and ice cream while giving baked goods a light and airy consistency. Inadequately structured or unsteady foams might result in compact products with diminished volume, leading to consumer dissatisfaction. To enhance the quality and shelf life of foams, food scientists must further their comprehension of the elements that affect foam stability, considering the inherent instability of foams.

A foam is a colloidal dispersion in which gas bubbles are scattered within a continuous liquid phase. The liquid phase can vary from a basic dispersion, such as egg white with a small amount of protein, to a more intricate combination that includes fat droplets in an emulsified form, ice crystals, or solid particles. Heat-setting is a procedure used to stabilise foam structures by denaturing proteins and transforming the liquid into a solid phase. This process is commonly used for foams seen in meringue and certain baked items.

9.3.1. Foam formation:

The foam production process depends on applying energy, usually by whipping, to absorb gas into a liquid, disintegrate large bubbles into smaller ones, and ensure that the liquid phase surrounds the gas bubbles as they are created.

The liquid contains a foaming agent that adsorbs at the surface of the liquid, lowering surface tension and creating a protective coating around the gas bubbles. Its low surface tension facilitates the quick spreading of the liquid surrounding the gas bubbles during whipping, preventing the freshly produced bubbles from bursting or merging.

9.3.2. Foam stability:

The assessment of foam stability can be accomplished by quantifying the decrease in volume over a given period. Stable foams maintain a generally constant volume, while unstable foams undergo substantial volume reduction due to air loss. Multiple factors contribute to decreased foam stability:

- Gravity-induced liquid film drainage happens when the liquid film drains downwards under the influence of gravity. This leads to the accumulation of liquid at the bottom of the container, causing the film to become thinner around gas bubbles. This reduction in thickness enhances the probability of gas leakage and decreases the foam volume.
- Delicate films have the potential to rupture, resulting in the merging of two adjacent films or the release of gas bubbles.
- Gas diffusion is the process by which gas molecules move from smaller bubbles to larger bubbles. This movement reduces the number of bubbles and causes the foam to shrink.
- While not as impactful, the evaporation of the continuous phase can cause gas bubbles to break and reduce the volume of foam.

Ensuring the prevention or reduction of film rupture, liquid drainage, and evaporation is essential to achieve stable and high-volume foam production.

Similar to emulsions, gas bubbles require a durable interfacial layer for stabilisation. Furthermore, the makeup of the ongoing phase greatly impacts the durability of the foam. Minimising evaporation is important by maintaining a low vapour pressure in the liquid phase, whereas it is vital to reduce drainage. The higher viscosity of the continuous phase impedes drainage, crucial for producing stable foam.

9.3.3. Foaming agents

Foaming agents are essential in determining the size and durability of foams. The foam's volume is determined by the foaming agent's capacity to adsorb at the interface and quickly decrease interfacial tension, along with the energy input during whipping. On the other hand, the stability of foam depends on the foaming agent's capacity to form a stable film at the interface and a thick continuous phase. Although all surfactants can reduce surface tension and create foams, not all of them are capable of producing stable foams. Certain surfactants can even inhibit foam formation.

A highly efficient foaming agent exhibits resemblances to an emulsifier, as it has to adsorb at the interface, diminish interfacial tension, and form a strong interfacial film that can withstand rupture. Not unexpectedly, proteins are commonly used as foaming agents in food applications. Egg white proteins are highly regarded for their exceptional foaming characteristics, making them ideal for creating culinary foams such as meringues, angel food cakes, and baked products. Additional proteins, such as gelatin and milk proteins, also function as highly efficient foaming agents.

When egg white is beaten, its proteins undergo denaturation at the boundary, forming a durable, elastic film at the interface due to their interactions with each other. Certain proteins found in egg whites contain carbohydrates. These proteins at the interface align themselves towards the aqueous phase when absorbed. Due to their hydrophilic properties, they have the potential to attract and bind water, which increases the thickness of the liquid and decreases its drainage. This, in turn, helps to maintain the stability of the foam.

Gelatin, a highly effective foaming ingredient, can froth when agitated in a heated solution, increasing its volume threefold. When cooled, gelatin undergoes solidification or gel formation, efficiently capturing air bubbles and stabilizing the foam. Marshmallows are a prime example of foams made using gelatin.

9.3.4. Foam suppressants:

Foam suppressants are essential in preventing the creation of long-lasting foams. For example, phospholipids and lipoproteins in egg yolks prevent egg whites from forming a stable froth when whipped. These components compete with egg white

proteins for adsorption on the surface, disrupting the creation of a stable protein film. Contrary to egg-white glycoproteins, phospholipids and lipoproteins are hydrophobic and tend to avoid water. As a result, they hinder the creation of a stable foam by not increasing the viscosity of the surrounding liquid. These molecules are called foam suppressants because they disrupt the development of foam by attaching themselves to the surface. This stops the desirable foaming agent from attaching and prevents the creation of stable foam. Foam suppressants do not possess the required characteristics to create a durable layer or sufficiently enhance the thickness of the continuous phase, hence rendering the production of stable foam unattainable. Typical substances used to reduce foam formation include fats, phospholipids, and other tiny molecules attracted to water and oil.

Salts function as foam suppressants by diminishing the strength of connections among protein molecules on the surface. This weakens the stability of the film that surrounds gas bubbles. Nevertheless, their influence is typically less substantial than surfactant molecules due to their limited ability to quickly adhere to the surface.

Antifoaming chemicals can disperse or prevent the production of foams. Antifoaming agents are frequently used in fats and oils to inhibit foam formation during frying. Like foam suppressants, antifoaming agents adsorb at the interface between air and liquid instead of foaming agents. However, unlike foam suppressants, they lack the required properties to function as foaming agents, preventing foam development.

9.4. EFFECT OF ADDED INGREDIENTS ON FOAM STABILITY

Additional components have a substantial impact on improving the durability of foam in various food items. For example, egg white foams such as meringue or angel food cake frequently incorporate sugar, which fulfils many roles. Sugar enhances the viscosity of the liquid, which helps maintain stability. Additionally, it protects the proteins from excessive denaturation and aggregation at the interface. Excessive protein interactions can cause the production of a rigid film that is easily broken, leading to a decrease in foam volume. Hence, it is imperative to use caution while adding sugar to egg white foams.

Different additives can improve or reduce foam stability. Gums, thickeners, sugar, acid, and solid particles are examples of foam stabilisers that help maintain

stability. On the other hand, lipids, phospholipids, small-molecule surfactants, salts, and acids are foam destabilisers that can weaken stability.

- Acidic substances, such as cream of tartar or lemon juice, are frequently employed to enhance the durability of foam. The addition of this substance lowers the pH, resulting in a decrease in the charge on protein molecules and usually bringing them closer to their isoelectric point. As a consequence, the strength and stability of the interfacial film are enhanced. Nevertheless, the addition of acid during the whipping process, especially when dealing with egg whites, is typically done towards the end to avoid any delay in foam production.
- Adding gums, thickening agents, or solid particles can increase the viscosity of the continuous phase. Whipped cream, for instance, depends on hardened fat globules arranged in a specific way inside the continuous liquid film to maintain its stability.

SELF-ASSESSMENT QUESTIONS

Short Questions:

1. Explain the role of emulsifiers in stabilizing emulsions and how they achieve this function at the interface between immiscible liquids.
2. Discuss the importance of foam stability in food products and the key factors that contribute to foam stability.
3. Explain Synthetic Emulsifiers and Surfactants
4. Discuss the significance of surface tension in forming and stabilising emulsions and foams.
5. Describe the impact of temperature fluctuations and storage conditions on the stability of emulsions and foams, and suggest strategies for maintaining stability under varying conditions.

Mark the statement as true or false

1. Emulsions consist of two immiscible liquids, with one liquid dispersed as droplets within the other(**true/false**)
2. Mayonnaise is an example of a transient emulsion. (**true/false**)
3. The stability of emulsions is influenced by factors such as the type and concentration of the emulsifier, droplet size, pH, and external conditions. (**true/false**)
4. Foams are colloidal dispersions in which gas bubbles are scattered within a continuous liquid phase. (**true/false**)
5. Synthetic emulsifiers, such as proteins and lecithin, are commonly used in food products due to their ability to create durable interfacial films. (**true/false**)

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