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मुक्त विश्वविद्यालय, प्रयागराज

MFN 117

FOOD SAFETY AND QUALITY CONTROL

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UTTAR PRADESH RAJARSHI TANDON OPEN UNIVERSITY
MFN 117 FOOD SAFETY AND QUALITY CONTROL

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FOOD SAFETY AND QUALITY CONTROL

Food safety and quality control is a system of practices, procedures, and policies that ensure the safety and quality of food. It involves identifying and controlling hazards, monitoring food at different stages of production, and taking corrective actions. Effective food standards and control systems are required to protect food production within the country as well as to facilitate trade with other nations. The course is designed with a focus to apprise the students about key concepts related to food safety and quality control. The learning material is directed primarily at PG students of Food Science, Nutrition Science and related subjects. The course has been divided into four important blocks i.e. Introduction of Quality Assurance and Quality Costs; Sampling, Product Evaluation and consumer protection and Concept of food safety, food contaminants, food borne diseases and food labeling. The blocks are divided into 12 units dealing with basics of quality assurance and will enable the students to develop deep knowledge of role of food safety and quality control principles; to understand the importance of food sampling, food analytical methods and food laws and regulations; to discuss the various food contaminants; food adulterants and processing contaminants present in food as well as explain the concept of food labelling. Each unit has a check your progress section, where you can self assess your learning outcome. Some suggestions for students for further reading are included at the end alongwith some relevant web links.



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BLOCK I - INTRODUCTION TO QUALITY ASSURANCE AND QUALITY COSTS

Block I explores key concepts related to quality in the food sector, providing a structured approach to understanding quality management. It consists of three units: Unit I, which introduces the fundamentals of Quality Assurance (QA); Unit II, which delves into Quality Assurance Programs (QAP) and their implementation; and Unit III, which examines the concept of Quality Costs (COQ) and its impact on efficiency and profitability.

Quality Assurance (QA) and Quality Control (QC) are integral components of quality management. Unit I provides an in-depth understanding of the fundamental concepts of QA and QC, emphasizing their significance in maintaining food quality and safety. It explores key dimensions of quality, the principles and functions of QA and QC, and the role of Total Quality Management (TQM) in the food industry. Additionally, the unit delves into Good Manufacturing Practices (GMP), the challenges associated with QA implementation and highlights strategies to enhance quality management systems in the food sector.

Unit II explores the essential concepts and frameworks that ensure product safety, quality, and consistency across industries, with a particular focus on the food sector. It provides an in-depth understanding of Quality Assurance Plans (QAP), key quality management principles, and internationally recognized standards such as HACCP, Codex Alimentarius, and the ISO 9000 family. These standards form a robust framework that organizations can implement to maintain high-quality production, prevent hazards, and comply with both regulatory and customer requirements.

Unit III explains the concept of Cost of Quality (COQ) which is crucial for ensuring organizational efficiency, customer satisfaction, and financial success. COQ includes all costs related to maintaining quality, encompassing prevention, appraisal, and failure costs. By systematically identifying, measuring, and analyzing these costs, organizations can make informed decisions to enhance quality, minimize waste, and improve profitability. This unit provides a comprehensive exploration of the COQ model, its key components, and its strategic role in building an effective quality management system.

UNIT-I INTRODUCTION TO QUALITY ASSURANCE

Structure

- 1.1 Introduction
- 1.2 Concept of Quality
- 1.3 Dimensions of Quality
- 1.4 Definitions
- 1.5 Quality Assurance vs Quality Control
- 1.6 Food Quality Tools: An Integrated Approach
- 1.7 Total Quality Management (TQM)
 - 1.7.1 Core Principles of TQM
 - 1.7.2 Benefits of TQM
- 1.8 Good Manufacturing Practices (GMP)
- 1.9 Challenges in Quality Assurance
- 1.10 Sum Up
- 1.11 Check your Progress

1.1 INTRODUCTION

Quality Assurance (QA) and Quality Control (QC) are fundamental components of quality management, ensuring that products and services meet established standards and fulfill customer expectations. This unit will help you comprehend with terms quality and food quality as well explain the dimensions of quality. The unit gives you an introduction to fundamentals of Quality Assurance (QA) and Quality Control (QC). Through this unit, we will try to understand the principles and functions of QA and QC. We will also get an idea of importance of total quality management in food industries. Further, we will also understand the concept of Good Manufacturing Practices (GMP) as well address the challenges in QA implementation.

Objectives

After learning this unit, you will be able to:

- comprehend the terms quality and food quality
- differentiate between quality assurance and quality control
- explain key approaches to food quality
- understand the concept of total quality management
- explain good manufacturing practices
- discuss challenges in implementation of QA

1.2 CONCEPT OF QUALITY

Quality is defined as the "degree to which a set of inherent characteristics fulfills requirements" (ISO 9000:2000). The concept of quality can vary depending on individual perspectives, making it essential to identify the target customers and understand their expectations of a "quality" product or service. Quality encompasses various attributes such as performance, reliability, safety, color, taste, feel, and smell, which are often outlined in formal specifications. These specifications allow for objective evaluation of the product or service. At its core, quality is about achieving customer satisfaction by meeting or exceeding expectations. In some cases, customers may also include regulatory authorities, whose requirements extend beyond compliance to include demonstrating the ability to maintain and ensure ongoing adherence to regulations. It is important to consider that "quality" should not be confused with the "standard" of a product or service. Organizations can deliver high-quality offerings at different levels of standard, depending on their goals and customer needs.

Food quality refers to the inherent characteristics of food that make it acceptable to consumers. This includes external attributes like appearance (shape, size, gloss, color, and consistency), flavor and texture as well as other aspects like food safety, addressing chemical, physical, and microbial concerns. Ensuring food quality is a critical requirement in food production, as consumers are highly sensitive to contamination that can occur during production. Additionally, many consumers depend on manufacturing and processing standards to understand the ingredients used, particularly due to dietary preferences, nutritional needs, or medical conditions. Food quality also encompasses product traceability, ensuring transparency regarding ingredient and packaging suppliers, and addresses labeling accuracy to provide correct ingredient and nutritional information.

1.3 DIMENSIONS OF QUALITY

The characteristics and features of a product that a supplier provides are shaped by the explicit and implicit needs of the customer. Ultimately, it is the customer who decides whether the product

meets their quality expectations. To ensure quality, standards must be defined to measure the product's characteristics, either through objective criteria, subjective judgment, or a combination of both. The various aspects of quality that customers seek to fulfill their needs are the driving factors in determining a product's attributes.

Dimensions of Quality for Manufactured Products:

- **Performance:** The product's main operating characteristics.
- **Features:** Additional elements that enhance the product's basic function.
- **Reliability:** The likelihood of the product lasting for a given period under specified usage conditions.
- **Conformity:** The extent to which the product's physical and performance attributes align with established standards.
- **Durability:** The product's lifespan before it begins to deteriorate or needs to be replaced.
- **Serviceability:** How easily and quickly the product can be repaired.
- **Aesthetics:** The sensory attributes of the product, such as its appearance, texture, taste, or smell.
- **Perceived Quality:** The subjective evaluation influenced by the product's image, branding, or advertising.

1.4 DEFINITIONS

Quality assurance is a comprehensive concept encompassing all factors that individually or collectively impact the quality of a product. According to ISO 9000, quality assurance is defined as "a part of quality management focused on providing confidence that quality requirements will be fulfilled." It is a management approach encompassing all planned and systematic actions required to ensure that a product, service, or outcome meets specified quality requirements and is fit for its intended use. A Quality Assurance program refers to the collective activities and processes designed to achieve and maintain the desired quality standards. In a food industry, quality assurance is categorized into key areas: development, quality control, production, distribution, and inspections.

Quality control refers to the operational techniques and activities used to meet quality requirements. It is an important component of any quality assurance system, which functions as a continuous process that monitors and modifies the production system to maintain the desired quality standards (Fig 1.1). According to ISO 9000, quality control is "a part of quality management focused

on fulfilling quality requirements." In the context of Good Manufacturing Practices (GMP), quality control involves sampling, specification, testing, documentation, and release procedures. These processes ensure that all necessary and relevant tests are conducted and that a product is released for use only after its quality has been verified.

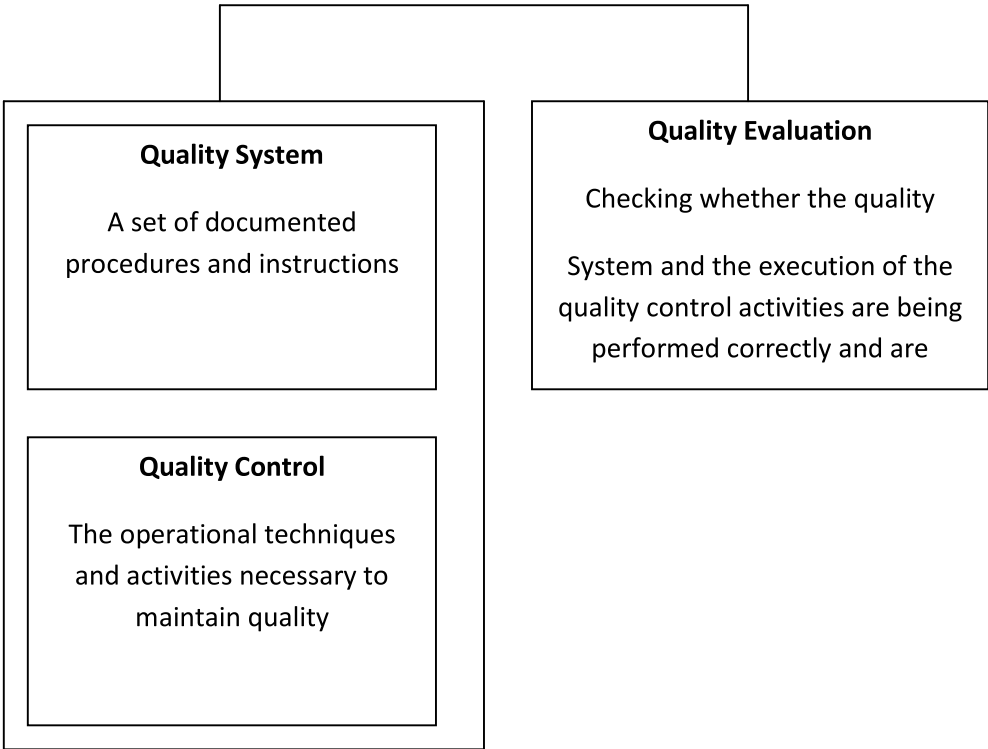


Fig. 1.1: Subsets of Quality Assurance Programme

1.5 QUALITY ASSURANCE VS QUALITY CONTROL

Quality Assurance (QA) and Quality Control (QC) are distinct yet complementary aspects of quality management. QA is a proactive, process-oriented approach focused on ensuring that the methods and systems used in product development are effective in preventing defects. It emphasizes improving processes, establishing quality management systems, and conducting periodic audits, with responsibility shared across the entire development team. In contrast, QC is a product-focused approach aimed at identification and correction of defects in the finished product before release. It involves testing, validation, and the use of specific tools and techniques to maintain product quality. While QA focuses on prevention and process improvement, QC ensures that the end product meets quality standards through defect detection and correction. Together, they work to ensure customer satisfaction and compliance with quality requirements. The differences between Quality Assurance and Quality Control are listed in Table 1.1.

Table 1.1: Differences between Quality Assurance and Quality Control

Aspect	Quality Assurance (QA)	Quality Control (QC)
Definition	A set of activities for ensuring quality in the processes by which products are developed.	A set of activities for ensuring quality in the actual products produced.
Nature	QA is a managerial tool focused on processes.	QC is a technical activity focused on identifying defects in the finished product.
Approach	Proactive – focuses on preventing defects by improving development and test processes.	Reactive – focuses on identifying and correcting defects after the product is developed.
Goal	To improve development processes and ensure no defects arise during production.	To identify and fix defects in the final product before release.
Focus Area	Ensures the quality of the processes used to create the product.	Focuses on the quality of the actual product being produced.
Key Objective	Finding and eliminating sources of quality problems to ensure customer requirements are consistently met.	Identifying defects in the finished product to ensure it meets the required quality standards.
Responsibility	The team involved in the product development is responsible for quality assurance.	Typically the responsibility of a specific team dedicated to testing and inspecting the product.
Activities	Prevention of quality problems through planned and systematic activities, including establishing quality management systems and conducting periodic conformance	Identification and correction of quality problems through techniques and tools used to maintain product, process, and service quality.

audits.

Documentation	Focuses on process documentation to ensure systematic quality management.	Focuses on testing records and documentation of defects identified in the product.
Outcome	Ensures processes are adequate to prevent defects.	Ensures the product is free of defects before release.
Example	Verification (e.g., ensuring processes comply with standards).	Validation (e.g., testing the product to ensure it meets quality requirements).

Functions of Quality Assurance (QA):

- Ensures adherence to the quality policies established by the company.
- Identifies and prepares necessary Standard Operating Procedures (SOPs) related to quality control.
- Verifies that products meet all applicable specifications and are manufactured in compliance with internal Good Manufacturing Practices (GMP) standards.
- Oversees quality monitoring and auditing activities.
- Continuously assesses operations, providing guidance to ensure full compliance with internal and external regulations.

Functions of Quality Control (QC):

- Manages the day-to-day quality control activities within the company.
- Conducts analytical testing of incoming raw materials and inspects packaging components, including labeling.
- Performs in-process testing, environmental monitoring, and operational inspections to ensure compliance.
- Carries out required testing on finished dosage forms to verify quality.
- Plays a critical role in selecting and approving qualified vendors for raw material supply. This includes testing representative samples and auditing vendor operations to ensure GMP compliance.
- Monitors and inspects environmental conditions in manufacturing areas to ensure compliance with standards for various dosage forms.

1.6 FOOD QUALITY TOOLS: AN INTEGRATED APPROACH

Several methods are employed to ensure both the quality and safety of food products. These methods are designed to maintain high standards throughout the production process, from raw material sourcing to the final product reaching consumers (Fig. 1.1). The key approaches include:

- **Total Quality Management (TQM):**

TQM is an extensive approach that focuses on continuous improvement in all areas of an organization. It involves all employees in the process of enhancing food quality and safety, with a strong emphasis on customer satisfaction. TQM integrates quality control into every part of the food production process, fostering a culture of proactive problem-solving and process optimization.

- **Quality Assurance (QA) / Quality Management (QM) – ISO Standards:**

Quality Assurance (QA) and Quality Management (QM) are frameworks for ensuring that food products meet specific quality standards. The ISO (International Organization for Standardization) standards, such as ISO 9001, are globally recognized guidelines that help organizations implement consistent and reliable quality systems. These standards help in setting up processes for systematic monitoring and controlling of quality to meet customer expectations and regulatory requirements.

- **Quality Systems:**

Quality Systems refer to the structured procedures and practices adopted by food companies to consistently deliver high-quality products. These systems involve standardized procedures for product development, production, packaging, and distribution, ensuring that every product produced meets the required specifications. These systems also provide a framework for identifying, documenting, and addressing any quality-related issues.

- **Hazard Analysis Critical Control Point (HACCP):**

HACCP is a preventive system used to ensure safety of food by identifying, evaluating, and controlling possible hazards throughout the production process. By identifying critical control points where risks may occur, HACCP helps food businesses prevent contamination, spoilage, and unsafe practices. The system relies on continuous monitoring and adjustments to maintain food safety standards and avoid foodborne illness.

- **Good Hygienic Practices (GHP) / Good Manufacturing Practice (GMP):**

These guidelines and procedures focus on maintaining a clean and sanitary environment throughout the food production process. Good Hygienic Practices (GHP) & Good Manufacturing Practices (GMP) set the foundation for a hygienic and safe production environment, which is critical in preventing contamination. Sanitation Standard Operating Procedures (SSOP) provide specific cleaning and sanitation steps. Prerequisite programs serve as a base upon which other safety and quality systems, such as HACCP, are built.

- **Quality Control (QC):**

Quality Control involves the routine inspection and testing of products to ensure they meet established quality standards. This process typically includes sampling, laboratory testing, and physical inspection to detect any defects or variations. QC ensures that only products that meet the required specifications are released to the market, helping to maintain consistency and safety in food products.

Each of these methods plays a vital role in ensuring that food products are both safe for consumption and of high quality, meeting the expectations of consumers and complying with industry regulations.

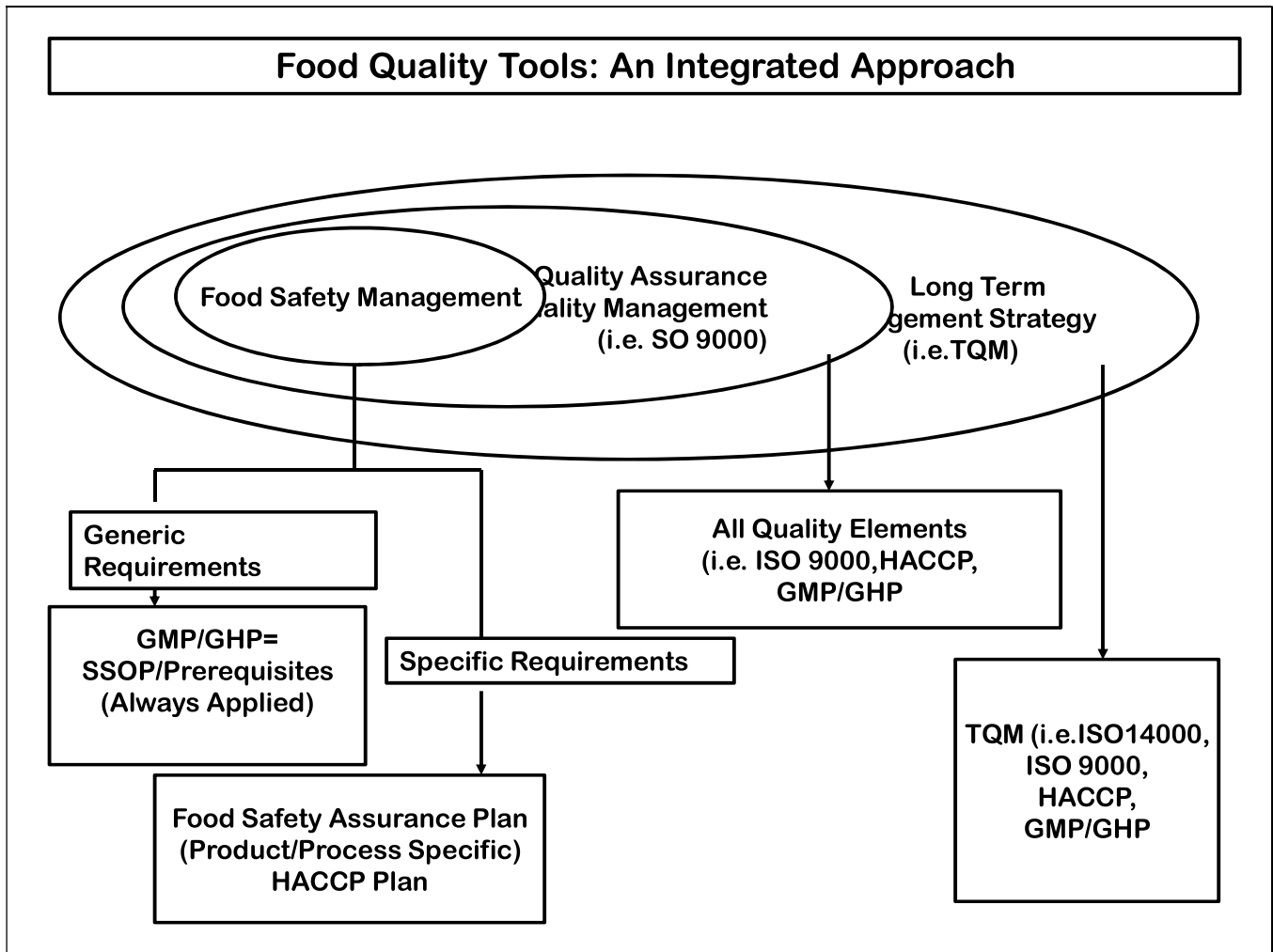


Fig. 1.1: Various Food Quality Tools

1.7 TOTAL QUALITY MANAGEMENT

Total Quality Management (TQM) is an integrated approach to managing an organization with the aim of achieving excellence by focusing on customer satisfaction. It is a structured system that incorporates the principles of product quality, process control, quality assurance, and continuous quality improvement to optimize the transformation processes of an organization. This approach ensures that customer needs are met in the most efficient and economical way while fostering a culture of continuous improvement.

1.7.1 Core Principles of TQM

- **Customer-First Orientation**

At the heart of TQM is a commitment to understanding and fulfilling customer needs. TQM emphasizes a customer-first mindset, aiming for customer retention, market share growth, and long-

term organizational success. By maintaining constant sensitivity to evolving customer and market demands, organizations can adapt and respond effectively to changes. Continuous collection and analysis of customer feedback are crucial for identifying requirements and improving products or services. This ensures alignment with customer expectations.

- **Integration Across the Organization**

TQM involves every part of the organization, from top management to frontline employees. All departments, processes, and individuals are connected in their commitment to achieving total quality. This collaboration ensures that each function contributes to the overall goal of satisfying customer needs and expectations.

- **Continuous Improvement**

TQM places a strong emphasis on the continuous improvement of processes, products, and services. This philosophy, often referred to as "Kaizen" in Japanese, is essential for achieving and maintaining the highest levels of performance. Continuous improvement involves identifying inefficiencies in current processes, implementing innovative solutions and regularly measuring and analyzing outcomes to ensure progress.

- **Quantitative Methods and Decision-Making**

TQM relies on quantitative tools and techniques to monitor, analyze, and improve processes. Data-driven decision-making is fundamental, ensuring that improvements are based on evidence rather than intuition. Tools such as statistical process control (SPC), Six Sigma, and root cause analysis (RCA) are often used to enhance precision and efficiency.

- **Process Control and Standardization**

Effective process control is a cornerstone of TQM. By standardizing processes, organizations can minimize variability, reduce errors, and consistently deliver high-quality outputs. Quality assurance systems, such as ISO standards, are often used to establish and maintain process controls.

1.7.2 Benefits of TQM

- **Enhanced Product and Service Quality:** TQM ensures that all products and services meet high-quality standards, resulting in satisfied customers and fewer complaints.
- **Improved Organizational Performance:** By focusing on continuous improvement and efficiency, organizations achieve better financial performance and sustainable growth.
- **Adaptability to Change:** TQM equips organizations with the tools and mindset needed to adapt to changing market demands and technological advancements.
- **Stronger Competitive Advantage:** Organizations that adopt TQM are better positioned to outperform competitors through superior quality, customer satisfaction, and innovation.

1.8 GOOD MANUFACTURING PRACTICES (GMP)

Good Manufacturing Practices (GMPs) are fundamental to ensuring quality. Also referred to as current Good Manufacturing Practices (cGMPs), they consist of a series of manufacturing and administrative procedures designed to ensure products are consistently produced to meet established specifications and customer expectations. In the food industry, GMP plays a crucial role in delivering safe and high-quality food. The three key elements of GMP are Food Safety, Good Practice, and Quality. A proactive approach to food safety is more effective than relying solely on final-stage testing or inspection. GMP ensures food safety through strict oversight of source materials, product design, and process control. By minimizing or eliminating contamination and false labeling, GMP helps protect consumers from misleading information and ensures they purchase safe products. Additionally, GMP serves as a valuable business tool, aiding manufacturers in improving compliance and overall performance. It establishes standardized manufacturing and quality control procedures to ensure products are consistently produced according to defined specifications.

Similar to other policy programs, GMP requires a structured, documented system that includes a written program, a maintenance schedule, and strong management commitment. The written program outlines the scope of GMP, designates responsible personnel, and details the key elements, such as parameters, monitoring activities, record-keeping, corrective actions, and verification processes. An essential component of the GMP framework is the focus on cleaning and hygiene, which is addressed under a dedicated subsection known as Good Hygienic Practices (GHPs). This integration ensures that hygiene standards are maintained consistently throughout the manufacturing process, further supporting product safety and quality.

1.9 CHALLENGES IN QUALITY ASSURANCE

Quality Assurance (QA) is a critical function in any organization, yet it comes with several challenges that can hinder its effectiveness. One major challenge is balancing cost and quality. Implementing comprehensive QA systems often requires significant investment in resources, technology, and personnel. Organizations may face pressure to cut costs, which can lead to inadequate testing, outdated equipment, or reduced training for employees, ultimately compromising quality. Another issue is managing resistance to change, especially in organizations with entrenched practices or a lack of quality culture. Employees and management may be reluctant to adopt new QA methods, tools, or technologies, viewing them as unnecessary disruptions rather than enhancements.

Technological advancements also pose challenges. While automation, AI, and data analytics have revolutionized QA, their rapid evolution makes it difficult for organizations to stay up-to-date. Integrating these technologies requires specialized skills and ongoing training, which some organizations may struggle to provide. Additionally, globalization and supply chain complexity create hurdles in maintaining consistent quality. With products and raw materials sourced from multiple regions, ensuring compliance with diverse regulatory requirements and standards becomes a daunting task. Differences in manufacturing practices, quality benchmarks, and communication barriers between suppliers can further complicate QA processes.

Compliance with regulations is another critical challenge. Organizations must navigate an ever-changing landscape of local and international quality standards and legal requirements, such as ISO certifications, FDA regulations, or industry-specific norms. Non-compliance can result in legal penalties, product recalls, and reputational damage. Lastly, lack of skilled personnel is a persistent challenge in QA. Effective quality assurance demands expertise in process evaluation, statistical analysis, and risk assessment. However, many organizations struggle to attract and retain professionals with these specialized skills, leading to inefficiencies in QA processes. QA requires a delicate balance of resources, technology, and compliance, all while managing internal resistance and external complexities. Addressing these challenges demands a proactive and adaptive approach, supported by strong leadership and a culture of quality.

1.10 SUM UP

This unit has updated you about the concept of Quality Assurance (QA) and Quality Control (QC). It helped you to differentiate between QA and QC. The unit apprised you to identify the significance of QA and QC in food industries. You also understood the impact of QA/QC on customer satisfaction, regulatory compliance, and organizational success. The unit further explained the principles of QA, importance and applications of quality frameworks such Total Quality Management, HACCP, industry-specific standards, including GMP. Additionally the unit discussed the common challenges in implementing QA/QC.

1.11 CHECK YOUR PROGRESS

1. Define:

a) Quality

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b) Food Quality

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c) Quality Assurance

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d) Quality Control

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e) Total Quality Management

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2. Differentiate between Quality Assurance and Quality Control.

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3. List the principles of Quality Assurance.

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4. Explain the principles of Total Quality Management.

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5. Discuss the challenges in implementing Quality Assurance.

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UNIT-II QUALITY ASSURANCE PROGRAMME

Structure

- 2.1 Introduction
- 2.2 Quality Assurance Plan
- 2.3 Key Elements of Quality Assurance
- 2.4 Good Practices
- 2.5 HACCP
- 2.6 ISO 9000
- 2.7 Codex Alimentarius
- 2.8 Sum Up
- 2.9 Check your Progress

2.1 INTRODUCTION

This chapter focuses on the critical concepts and frameworks that ensure the safety, quality, and consistency of products across various industries. It will provide an in-depth understanding of Quality Assurance Plans (QAP), key quality management principles, and internationally recognized standards such as HACCP (Hazard Analysis and Critical Control Points), Codex Alimentarius, and the ISO 9000 family. These systems and standards are essential in creating a robust framework that organizations can implement to deliver high-quality products, prevent hazards, and comply with both regulatory and customer requirements. Through this chapter, we will explore the key elements of quality assurance, good practices for maintaining quality, the importance of hazard management in food safety, and how global standards contribute to maintaining uniformity and safety in production and distribution processes. By understanding these systems, organizations can improve operational efficiency, mitigate risks, and enhance customer satisfaction.

Objectives

After learning this unit, you will be able to:

- define quality assurance plan
- identify key elements of a quality assurance
- understand concept of good practices for QA
- explain the HACCP system and its principles
- understand the role of Codex standards
- understand the fundamentals of ISO 9000 standards
- able to integrate HACCP, Codex and ISO 9000 in quality assurance

2.2 QUALITY ASSURANCE PLAN

Quality assurance encompasses the planning and monitoring of all aspects related to quality within an organization. Its primary goal is to build confidence, both internally within the organization and externally among its customers, that their requirements will be consistently met. As quality assurance evolves beyond traditional quality control, it incorporates several key elements, including:

- Defining a quality policy and objectives;
- Developing a comprehensive quality manual;
- Ensuring the competency of personnel;
- Conducting regular internal audits;
- Addressing and eliminating the root causes of identified problems;
- Periodically reviewing the system with the involvement of top management.

Above all, the focus shifts from merely detecting nonconformities to proactively preventing them. In the food industry, the implementation of a quality assurance system requires adherence to good practices, such as Good Hygienic Practices (GHP), Good Agricultural Practices (GAP), and Good Environmental Practices (GEP). These practices form the foundation for introducing quality assurance standards. Additionally, compliance with established standards such as GMP (Good Manufacturing Practices), HACCP (Hazard Analysis and Critical Control Points), ISO 9000, and Codex Alimentarius standards is crucial for effectively managing potential hazards and ensuring food safety.

2.3 KEY ELEMENTS OF QUALITY ASSURANCE

As quality assurance evolves beyond traditional quality control, it emphasizes a systematic and proactive approach to ensuring consistent quality. It incorporates several key elements that are vital for building a robust quality assurance system:

- **Defining a Quality Policy and Objectives**

Quality Policy: A quality policy is a formal statement from top management outlining the organization's commitment to maintaining and improving quality. It serves as a guiding framework for all quality-related activities and ensures alignment with the company's mission, vision, and values. Eg. "Our policy is to deliver safe and high-quality products that meet customer expectations and comply with regulatory requirements."

Quality Objectives are measurable goals derived from the quality policy, such as reducing defect rates, improving customer satisfaction, or enhancing process efficiency. These objectives should follow the SMART criteria i.e. being Specific, Measurable, Achievable, Relevant and Time-bound).

- **Developing a Comprehensive Quality Manual**

A quality manual is a clear, consistent guide for employees and ensures compliance with internal and external quality standards. It serves as a central document detailing the organization's quality management system (QMS) which includes:

- An overview of the quality policy and objectives.
 - Roles and responsibilities of personnel in quality-related processes.
 - Detailed standard operating procedures (SOPs).
 - References to applicable regulations, standards, and guidelines (e.g., ISO 9001, HACCP).
 - Instructions for monitoring, documentation, and record-keeping.
- **Ensuring the Competency of Personnel**
Employees must be adequately trained on their roles, SOPs, and quality standards. This includes both initial training and periodic refresher courses. Skill assessment of the employees should be conducted through regular evaluations to ensure employees have the necessary knowledge and skills to perform their tasks. In industries like food or pharmaceuticals, certifications (e.g., HACCP training) may be required to demonstrate expertise. It is important to foster a culture where employees are aware of their contribution to quality and are encouraged to suggest improvements.
 - **Conducting Regular Internal Audits**

Internal audits are systematic examinations of the QMS to ensure compliance with established policies, procedures, and standards. They are conducted at a specified frequency to review processes, documents, and practices to identify nonconformities in the QMS. The findings are documented,

including areas of strength and opportunities for improvement. Internal audits improve transparency, identify areas for improvement, and ensure preparedness for external audits.

- **Addressing and Eliminating the Root Causes of Identified Problems**

Root Cause Analysis (RCA) is a structured method to identify the underlying causes of problems, rather than addressing symptoms. Common RCA tools include fishbone diagram, 5 Whys Analysis and Failure Mode and Effects Analysis (FMEA). Corrective actions are taken as immediate steps to fix the problem and prevent its recurrence whereas preventive actions are proactive measures to mitigate risks and prevent potential problems from occurring.

- **Periodically Reviewing the System**

Scheduled meetings should be conducted where top management evaluates the effectiveness and efficiency of the QMS on the basis of performance metrics, progress on quality objectives, analysis of customer feedback and complaints, effectiveness of corrective and preventive actions etc.

These key elements collectively transform quality assurance into a comprehensive and proactive system. By integrating planning, documentation, training, monitoring, problem-solving, and management oversight, organizations can ensure consistent quality, build customer confidence, and maintain a competitive edge.

2.4 GOOD PRACTICES

- **Good Agricultural Practices (GAPs)**

Good Agricultural Practices (GAPs) refer to a set of principles, guidelines, and practices that ensure agricultural production is carried out sustainably, safely, and efficiently. These practices focus on producing high-quality crops and livestock while minimizing risks to food safety, environmental health, and worker well-being. GAPs encompass the entire agricultural process, from land preparation and planting to harvesting, storage, and transportation. Key components of GAPs include the use of safe and sustainable inputs, such as high-quality seeds, biofertilizers, and environmentally friendly pest control methods, to minimize chemical residues in food. Soil and water management is another critical aspect, ensuring the preservation of natural resources and preventing contamination of water supplies. For instance, regular soil testing and irrigation practices are adopted to prevent overuse of fertilizers

and water. GAPs also emphasize hygienic practices in handling crops and livestock, such as proper sanitation during harvest, cleaning of equipment, and storage in conditions that prevent contamination or spoilage.

Additionally, GAPs include worker safety and welfare, ensuring that laborers are trained in safe handling practices and provided with protective gear when dealing with chemicals or machinery. These practices align with global food safety standards such as HACCP, Codex Alimentarius, and ISO certifications, ensuring compliance with domestic and international regulations. By adhering to GAPs, farmers can not only enhance the quality and safety of their produce but also protect the environment, boost consumer confidence, and secure access to global markets. GAPs play a vital role in addressing challenges such as food security, climate change, and the increasing demand for sustainable agricultural practices.

- **Good Hygiene Practices (GHPs)**

Good Hygiene Practices (GHPs) are a comprehensive set of guidelines designed to ensure cleanliness and hygiene throughout all stages of food production, handling, storage, and distribution. The primary goal of GHPs is to prevent contamination, safeguard food safety, and minimize the risk of foodborne illnesses. These practices apply to everyone involved in the food supply chain, from agricultural workers to food processors, distributors, and retailers. Key elements of GHPs include maintaining high standards of personal hygiene, where workers are required to wash their hands frequently with soap and water, wear clean protective clothing such as gloves, aprons, and hairnets, and avoid working when ill or injured to prevent contamination. Equally important is the hygiene of facilities and equipment, which must be kept clean and sanitized regularly. This includes cleaning and disinfecting surfaces, tools, and machinery that come into contact with food, ensuring proper waste disposal, and maintaining pest control measures to prevent contamination by insects or rodents.

Water and raw material hygiene also play a critical role in GHPs, as only potable water and safe, high-quality raw materials should be used to prevent introducing hazards into the food production process. Storage and transportation of food products are governed by strict temperature controls and hygienic conditions to avoid spoilage and contamination. Regular training of personnel is another critical component, ensuring that workers are well-informed about hygienic practices, food safety risks, and regulatory requirements. GHPs also emphasize the proper design and maintenance of infrastructure, including separate areas for raw and finished products, adequate ventilation, and the availability of handwashing stations. By implementing GHPs, food businesses can not only meet

national and international food safety standards like HACCP and Codex Alimentarius but also build consumer trust, reduce economic losses from product recalls, and contribute to public health protection.

- **Good Manufacturing Practices (GMPs)**

They are a set of guidelines that ensure the consistent production and control of products to meet quality standards. Please refer to section 1.8 of Unit I.

- **Good Environmental Practices (GEPs)**

Good Environmental Practices (GEPs) refer to a set of strategies and actions designed to minimize the negative impact of human activities on the environment while promoting sustainability and resource conservation. These practices are especially critical in industries like agriculture, food processing, manufacturing, and construction, where operations can significantly affect ecosystems, water resources, air quality, and soil health. GEPs focus on integrating environmentally friendly methods into day-to-day operations to ensure sustainable growth and compliance with environmental regulations.

A key aspect of GEPs is efficient resource management, which includes conserving water, energy, and raw materials. For example, industries are encouraged to adopt water-saving technologies, recycle wastewater, and use renewable energy sources like solar or wind power. Similarly, waste management is an essential component, involving the segregation, reduction, and recycling of waste materials to prevent landfills from overflowing and reduce environmental pollution. The use of biodegradable and recyclable packaging materials is another practice that supports sustainability. In agriculture, GEPs promote the use of sustainable farming methods, such as crop rotation, organic farming, integrated pest management (IPM), and the reduction of synthetic fertilizers and pesticides. These practices protect soil health, reduce chemical runoff into water bodies, and enhance biodiversity. Moreover, GEPs emphasize pollution control measures, such as installing air and water filtration systems to reduce emissions and effluents. Preserving natural habitats and biodiversity through reforestation, habitat restoration, and conservation projects is another critical component. Organizations must train staff to follow eco-friendly practices and involve local communities in environmental conservation efforts. By adhering to GEPs, businesses not only comply with environmental laws and standards but also enhance their reputation, reduce operational costs, and contribute to a healthier planet for future generations.

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

Adopting a proactive approach is essential for ensuring food safety. While end-product inspection and testing play a role, they are time-consuming, costly, and only identify issues after they occur. In contrast, the HACCP (Hazard Analysis and Critical Control Points) system enables the identification and control of hazards at any stage of processing or manufacturing. This approach allows for timely corrective actions, ensuring the production of safe, high-quality products. Additionally, HACCP helps producers, processors, distributors, and exporters optimize resources efficiently and cost-effectively to maintain food safety standards. HACCP has been increasingly implemented across all areas of food manufacturing, processing, and service, ranging from large-scale industrial operations to small cottage industries and even domestic food preparation. Within the HACCP framework, the terms "hazard" and "threat" carry specific meanings distinct from their everyday usage. A "hazard" refers to a source of risk, defined as unacceptable contamination, growth, or survival of microorganisms that may compromise safety or shelf-life, as well as the creation or persistence of microbial metabolites that could affect these factors. Hazards are evaluated based on their severity and threat, with food safety hazards considered more critical than those affecting shelf-life. The effective development and implementation of HACCP require the involvement of a multidisciplinary team. This team typically includes a microbiologist, process supervisor, engineer, and quality assurance manager, each contributing their specialized expertise to address and resolve potential issues comprehensively.

Principles of HACCP

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

- Conduct a hazard analysis.
- Determine the Critical Control Points (CCPs).
- Establish critical limits.
- Establish a system to monitor control of the CCP.
- Establish corrective action to be taken when monitoring indicates that a particular CCP is not under control.
- Establish procedures to verify that the HACCP system is working effectively.
- Establish documentation concerning all procedures and records

To apply these principles in practice it is necessary to go through a series of steps outlined in Table 2.1.

Table 2.1: Steps in HACCP application

Sl. No.	Steps Required	HACCP Principle Involved
1	Assemble the HACCP team	
2	Describe the product	
3	Identify intended use	
4	Construct flow diagram	
5	On-site confirmation of flow diagram	
6	List all potential hazards	Principle 1
7	Conduct a hazard analysis	
8	Determine control measures	
9	Determine CCPs	Principle 2
10	Establish critical limit for each CCP	Principle 3
11	Establish a monitoring system for each CCP	Principle 4
12	Establish corrective action for deviations that may occur	Principle 5
13	Establish verification procedures	Principle 6
14	Establish documentation of procedures and records	Principle 7

- **Hazard analysis** is a critical step in the HACCP system, focusing on identifying potential hazards in the food production process that could compromise consumer safety. This step requires a systematic approach, thoroughly examining all raw materials, ingredients, processing steps, and potential sources of contamination across packaging, distribution, and storage. The analysis should point out raw materials and ingredients that might harbor harmful microorganisms or toxic metabolites, assess the likelihood of these hazards occurring, and evaluate the severity of their potential health effects. Additionally, contamination risks at various processing stages must be considered, along with the physical and chemical properties of intermediates and final products. To

manage these hazards effectively, it is essential to identify control measures, such as lethal or bacteriostatic processes, to minimize risks.

- Identification of Critical Control Points (CCPs) is a key step in the HACCP system, focusing on determining specific points in the production process where hazards can be controlled or eliminated to ensure the safety of the final product. CCPs are those critical stages where failing to manage a hazard would result in an unacceptable risk to consumer safety or product integrity. To identify CCPs, a hazard analysis is first performed to pinpoint potential hazards and the stages in production where they are most likely to arise. A decision tree is then used to determine which steps should be classified as CCPs. These decision trees guide the identification process by asking a series of questions, such as whether a control measure exists at a given step or if a hazard can be eliminated or reduced to a safe level. Once CCPs are identified, specific control measures are put in place to ensure that the hazards are properly controlled or removed.
- **Establishment of CCP Critical Limits:** Once Critical Control Points (CCPs) are identified, the next step is to establish critical limits for each CCP. Critical limits are specific thresholds or parameters that must be met to ensure that the hazard is effectively controlled at each CCP. These limits can be derived from regulatory standards, scientific research, industry norms, or other reliable sources. Critical limits may involve physical, chemical, or biological parameters, such as temperature, pH, water activity, or microbial count. It is essential that critical limits are measurable and can be monitored in real-time or near-real-time. This enables the detection of any deviations from the set limits, prompting timely corrective actions to prevent unsafe food products from being produced. Establishing critical limits should be based on scientific and technical data, with input from food safety experts, microbiologists, process engineers, and other relevant personnel. Once the critical limits are defined, they must be documented and communicated clearly to all personnel involved in the production process. Additionally, these limits should be regularly reviewed and updated to ensure they remain effective in controlling the identified hazards.
- **Monitoring Procedures for CCPs:** After defining critical limits for each CCP, it is crucial to implement monitoring procedures to ensure these limits are consistently met. Monitoring involves measuring or observing a parameter or CCP at specific stages in the process, allowing for the early detection of any deviations from the established critical limits. The frequency of monitoring should be determined based on the risk level of the CCP and the likelihood of deviations. Monitoring should occur often enough to identify any issues before a hazard arises. Monitoring records should be meticulously kept, documenting the date and time of the measurement, the individual responsible for the monitoring, and the results obtained. These records are vital for confirming that

the process remains under control and for identifying trends or patterns that could signal the need for corrective actions. Monitoring procedures are essential to ensure critical limits are consistently met and deviations are detected promptly.

- **Protocols for CCP Deviations:** When a deviation from the established critical limit occurs at a CCP, specific procedures must be followed to ensure the issue is addressed quickly and appropriately. Deviations may happen due to equipment failure, human error, or unforeseen circumstances. The protocols for managing these deviations should be designed to identify, document, and resolve the issue in a timely manner, preventing any potential harm to the consumer or product. Corrective actions could involve reprocessing, discarding affected products, adjusting the process, or implementing additional control measures. Documentation of the deviation and the corrective actions taken is crucial for maintaining an accurate record and for ensuring that the issue is thoroughly investigated to prevent future occurrences.
- **Verification** is the process of assessing the effectiveness of the HACCP system in controlling hazards and ensuring food safety. It involves a series of activities designed to confirm that the system is functioning as intended and that identified hazards are being properly controlled. Verification activities include reviewing and updating the HACCP plan, evaluating monitoring data and records, conducting internal audits, and verifying that corrective actions have been implemented when needed. The goal is to ensure that the HACCP system operates effectively, identifying and addressing any deficiencies or weaknesses. The verification process should be carried out by trained individuals who are independent of the HACCP team and have the necessary expertise to evaluate the system's performance.
- **Record Keeping** is a vital component of a HACCP plan, serving to provide a detailed history of the HACCP system's implementation, including all procedures followed, activities conducted, and any deviations that occurred. This documentation is crucial for demonstrating that the system is being properly executed and that the products are safe for consumption. Records should be maintained for all CCPs, documenting details such as monitoring results, corrective actions taken, and verification activities. Additional records should include product specifications, supplier information, and other relevant data related to food safety. For example, records may include temperature logs for refrigeration units or drying chambers, pH measurements for acidified products, or microbial test results for ready-to-eat foods. Records should be stored securely and be readily accessible for inspection by regulatory agencies or auditors. Effective record keeping is essential for the success of a HACCP plan.

2.6 ISO 9000

The ISO 9000 family refers to a set of international standards for quality management systems (QMS) and is designed to help organizations ensure they meet the needs of customers and other stakeholders while complying with regulatory requirements. The standards are developed and published by the International Organization for Standardization (ISO). ISO 9000 standards are not only applicable to food manufacturing companies but can also be implemented in service industries, healthcare, and other sectors. The focus on customer satisfaction, process improvement, and systematic evaluation helps organizations maintain high standards and achieve business excellence. The ISO 9000 family includes several standards, the most widely known and implemented being **ISO 9001**.

Key standards of the ISO 9000 family:

1. **ISO 9000**: This is the fundamental standard that outlines the basic principles and vocabulary related to quality management systems. It provides an introduction to the concepts and terminology used in the other standards within the family.
2. **ISO 9001**: This is the most commonly implemented standard in the ISO 9000 family. It provides the requirements for a QMS and is used by organizations to demonstrate their ability to consistently provide products and services that meet customer and regulatory requirements. Certification to ISO 9001 is often sought by companies to enhance their marketability and improve their operational performance.
3. **ISO 9004**: This standard provides guidance for organizations on how to achieve sustained success through a quality management approach. Unlike ISO 9001, which focuses on meeting customer requirements, ISO 9004 goes further to help organizations focus on long-term effectiveness and continuous improvement.
4. **ISO 19011**: This standard offers guidelines for auditing quality management systems. It is often used by organizations to train internal and external auditors, providing a framework for conducting effective audits of QMS.
5. **ISO 9000:2015**: This is the most recent version of the family, emphasizing risk-based thinking and a more streamlined approach to managing quality. It focuses on creating value for both customers and stakeholders and on continuous improvement.

ISO 9001 is a globally recognized standard for quality management systems (QMS) that defines the requirements organizations must follow to consistently provide products and services that meet

customer expectations and regulatory requirements. It is the most widely recognized standard within the ISO 9000 family and is applicable to organizations of any size or industry. The standard is built on number of key principles, including leadership, customer focus, process approach, engagement of people, evidence-based decision-making, improvement, and relationship management. The core of ISO 9001 is to establish a robust QMS that ensures the consistent delivery of quality products and services. To meet ISO 9001 standards, organizations must define their quality policy and objectives, understand the needs of customers, and implement processes that ensure these needs are met. The standard emphasizes the importance of a structured approach to process management, requiring organizations to identify and manage processes systematically, while also fostering a culture of continuous improvement. A significant component of ISO 9001 is the adoption of a risk-based approach, which encourages organizations to identify potential risks to the quality of products or services and to proactively manage these risks to minimize adverse effects. It also requires regular monitoring, measurement, and analysis of processes to assess their effectiveness and make informed decisions.

ISO 9001 certification involves an external audit by a certification body, which evaluates the organization's adherence to the standard's requirements. The standard does not specify how the organization should achieve these requirements, offering flexibility in implementation based on the company's context. However, it requires organizations to document their quality management system, establish measurable objectives, and ensure that personnel are properly trained and engaged. By achieving ISO 9001 certification, organizations demonstrate their commitment to quality, enhance customer satisfaction, and establish a foundation for continuous improvement. The certification can provide a competitive advantage, improve operational efficiency, reduce waste, and create a culture of quality throughout the organization.

2.7 CODEX ALIMENTARIUS COMMISSION

The Codex Alimentarius is an extensive compilation of internationally recognized food standards, codes of practice, guidelines, and recommendations. It was established to safeguard consumer health and promote fair practices in the global food trade. Derived from Latin, meaning "food code," the Codex sets both general and specific food safety standards to ensure the quality and safety of food, whether for local markets or international trade. Codex Alimentarius plays a pivotal role in safeguarding consumer health, promoting fair trade, and ensuring the global food supply is safe, hygienic, and of high quality. Through its standards and guidelines, it fosters trust and cooperation in the international food trade, benefiting both producers and consumers.

The primary goals of the Codex Alimentarius are:

- **Protecting Consumer Health:** Ensuring that food products are safe to consume, free from disease-causing organisms, and of high quality.
- **Ensuring Fair Practices in Food Trade:** Promoting consistency and fairness in the global food market, safeguarding importing countries from risks to their plant and animal health.

The Codex Alimentarius is overseen by the Codex Alimentarius Commission, an intergovernmental body where all member countries have voting rights. The commission operates through Executive Committee and Codex Committees which are responsible for drafting specific standards and guidelines. They focus on particular areas such as food hygiene, contaminants, labeling, and specific product categories. Once drafted, the standards are reviewed and adopted by the Codex Alimentarius Commission, ensuring global consensus.

Key Features of the Codex Alimentarius

1. **Global Standards for Food Safety:** The Codex provides internationally agreed-upon standards to ensure food is safe for human consumption and free from harmful contaminants.
2. **Support for Food Hygiene and Safety Practices:** By promoting HACCP and other hygiene practices, the Codex helps reduce foodborne illnesses and ensures food safety at every stage of production and distribution.
3. **Facilitation of International Trade:** Adhering to Codex standards ensures that food products meet the requirements of importing countries, fostering smooth international trade and minimizing disputes.
4. **Prevention of Disease Spread:** The Codex emphasizes that food should not carry pathogens or contaminants that could harm the health of plants or animals in importing nations.

Codex standards typically focus on product characteristics and may address all government-regulated attributes relevant to a commodity, or they may focus on a single characteristic. For example, maximum residue limits (MRLs) for pesticide or veterinary drug residues in foods are standards that pertain to a specific characteristic. Codex also sets general standards for food additives, contaminants, and toxins, which include both broad and commodity-specific provisions. The Codex General Standard for the Labeling of Pre-packaged Foods applies to all foods in this category. Since these standards are based on product characteristics, they are applicable to products traded globally. Codex also includes

methods of analysis and sampling, such as those for contaminants and pesticide or veterinary drug residues, which are considered part of the Codex standards.

Codex Codes of Practice are hygienic practices outlined to be followed during processing, production, manufacturing, transport, and storage practices for foods products, ensuring their safety and suitability for consumption. For food hygiene, the foundational text is the Codex General Principles of Food Hygiene, which incorporates elements like HACCP, CCP, and FSMS. The Codex Alimentarius serves as a benchmark for food safety standards worldwide, helping member countries establish and align their national regulations with international norms. By participating in the Codex Commission, countries can contribute to the development of global food standards while ensuring their trade practices comply with international expectations.

2.8 SUM UP

This unit has helped you understand how a quality assurance plan integrates into an organization's overall quality management system (QMS) and the steps involved in its development and implementation. Through this unit you were able to identify the core components of a quality assurance plan and understand the importance of documentation in a QA plan. The unit also fostered an understanding of the principles of good hygienic practices (GHP), good agricultural practices (GAP), and good environment practices (GEP) that can contribute to a successful QA plan. The unit also explained the role of HACCP system as a proactive approach to food safety and quality management. You also understood about the role of Codex Alimentarius in establishing global food safety standards and ensuring international trade. The unit also emphasized on ISO 9000 family of standards, specially ISO 9001 as the standard for quality management systems.

2.9 CHECK YOUR PROGRESS

1. Define:

a) Quality Manual

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b) Hazard Analysis

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c) CCP

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d) Verification

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2. Explain the key elements of quality assurance.

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3. Discuss the principles of HACCP.

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4. Explain the key features of Codex Alimentarius.

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5. Write a short note on ISO 9001.

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UNIT-III QUALITY COSTS: MEASUREMENT AND ANALYSIS

Structure

- 3.1 Introduction
- 3.2 What is Cost?
- 3.3 Quality Costs
- 3.4 Types of quality Costs
 - 3.4.1 Assurance Costs
 - 3.4.2 Prevention Costs
 - 3.4.3 Appraisal Costs
 - 3.4.4 Failure Costs
- 3.5 Measurement of Quality Costs
- 3.6 Importance of Quality Costs
- 3.7 Sum Up
- 3.8 Check your Progress

3.1 INTRODUCTION

The concept of Quality Costs (COQ) plays a vital role in ensuring organizational efficiency, customer satisfaction, and financial success. COQ encompasses all costs associated with maintaining quality, from prevention and appraisal to managing failures. It highlights the principle that investing in prevention and quality assurance can significantly reduce the cost of failure, which often arises from defective products or services. By systematically identifying, measuring, and analyzing these costs, organizations can make informed decisions that enhance quality, minimize waste, and improve profitability. This chapter provides a comprehensive understanding of the COQ model, its components, and its strategic significance in developing a robust quality management system.

Objectives

After learning this unit, you will be able to:

- explain cost and its types
- define the concept of Cost of Quality (COQ)
- identify and categorize the components of quality costs
- understand the role of COQ in improving product and service quality
- differentiate between different types of quality cost
- analyze the COQ model
- understand the importance of Cost of Quality (COQ)

3.2 What is Cost?

Cost refers to the monetary value or expenditure required to produce, acquire, or maintain a product, service, or activity. It encompasses all the resources, such as money, time, labor, and materials, sacrificed to achieve a specific goal. Costs are broadly classified into various categories to provide clarity for financial analysis and decision-making. Fixed costs remain constant regardless of production levels, such as rent, salaries, and insurance, whereas variable costs fluctuate in proportion to output, like raw materials and utilities. Direct costs are explicitly tied to a specific product or service, such as raw materials and direct labor, while indirect costs, like administrative expenses or factory maintenance, support overall operations without being directly attributable to a single product. Opportunity cost represents the benefits foregone from the next best alternative when a decision is made, while sunk costs reflect past expenditures that cannot be recovered. Marginal cost, on the other hand, measures the additional expense incurred by producing one extra unit of a product. Understanding costs is fundamental to effective financial management, helping businesses set pricing strategies, budget effectively, evaluate profitability, and make informed operational and investment decisions. A clear understanding of costs also aids in reducing inefficiencies, optimizing resource allocation, and achieving long-term organizational goals. According to Horngren et al. (2005) cost is "a resource sacrificed or foregone to achieve a specific objective, measured in monetary terms." Similarly, CIMA (Chartered Institute of Management Accountants) defines cost as "the amount of expenditure, actual or notional, incurred on or attributable to a specific thing, such as a product, activity, or service." Anthony and Reece (1995) elaborated that cost represents "the economic value of resources consumed in carrying out an activity to produce a product or deliver a service."

3.3 QUALITY COSTS

Quality costs are similar to other types of costs, such as maintenance, project, production, and sales costs, in that they can be measured and analyzed. These costs are present at every stage of the

product life cycle and across all operational levels within the company. Just like other business expenses, quality costs can be tracked and assessed to understand their impact on the organization.

Quality costs refer to the total expenses incurred by an organization to ensure that its products or services meet specified quality standards. These costs are a critical part of quality management systems and are typically categorized into four main types: prevention costs, assurance costs, appraisal costs, and failure costs (Fig. 3.1). Prevention costs are proactive investments made to avoid defects, such as employee training, quality improvement programs, and process enhancements. Appraisal costs are associated with detecting defects during production, including inspection, testing, and quality audits. Internal failure costs arise when defects are identified before the product reaches the customer and include expenses like rework, scrap, and downtime. External failure costs, the most damaging to a company's reputation, occur when defective products reach customers, leading to warranty claims, product recalls, customer dissatisfaction, and potential legal liabilities. Effective management of quality costs not only reduces waste and inefficiencies but also enhances customer satisfaction, brand loyalty, and profitability. Organizations that prioritize quality costs can identify opportunities for improvement, minimize defect-related expenses, and create a culture of continuous improvement, ensuring long-term sustainability and competitiveness in the market.

Quality costs serve as a crucial management tool, offering the following benefits:

- A framework for evaluating the overall effectiveness of the quality program.
- A structured approach to developing programs that address overarching needs.
- A method for identifying problem areas and prioritizing actions accordingly.
- A technique for optimizing efforts across various quality activities.
- Valuable insights for pricing products or preparing competitive bids.

This makes quality cost analysis an essential element of strategic decision-making and operational efficiency.

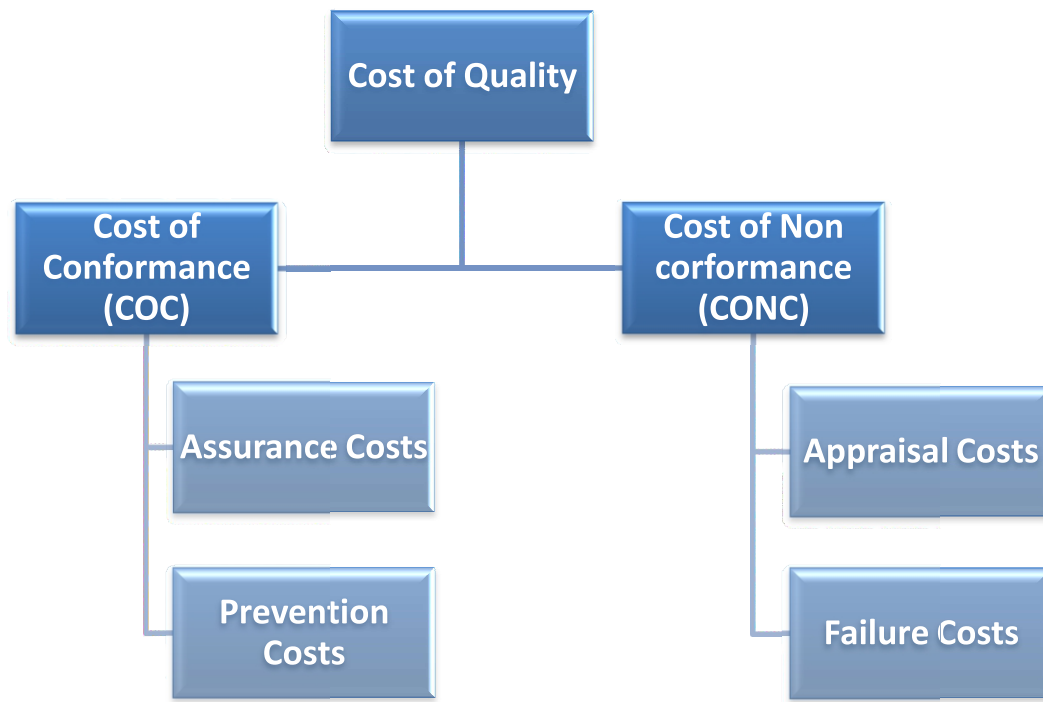


Fig. 3.1: Classification of Quality Costs

3.4 TYPES OF QUALITY COSTS

The Cost of Conformance (COC), also referred to as the Cost of Good Quality (COGQ), encompasses the expenses associated with performing quality work, implementing quality improvements, and meeting quality objectives. These costs focus on ensuring quality and preventing poor quality. The Cost of Conformance is further divided into two categories: Assurance Costs, which involves activities that provide confidence in the quality system, and Prevention Costs, which includes efforts to avoid defects or quality issues before they occur.

3.4.1 Assurance Costs

These costs are related to maintaining and ensuring quality standards through various requirements, systems, procedures, control measures, and audits. They include expenses for establishing methods and processes, conducting process capability studies, designing robust products, providing proper employee training for quality performance, assessing and certifying suppliers, conducting quality audits to verify system functionality, acquiring necessary tools, and planning for quality. Quality assurance instills confidence in the system that upholds the quality of deliverables.

3.4.2 Prevention Costs

Preventive activities are actions undertaken to eliminate the root cause of potential non-conformities or other undesirable situations. These activities ensure that processes and procedures consistently produce the desired outcomes, meeting requirements without failure. Examples of preventive activities include preventive maintenance, quality education and training, process validation, procedure verification, customer-oriented training, and design reviews. By focusing on proactive measures, these activities help maintain system reliability and ensure conformance to standards. Prevention costs refer to the expenses associated with efforts to eliminate defects before they occur, ensuring that errors are avoided and tasks are completed correctly from the start. These costs may include activities like verifying incoming materials, processes, products, and services to ensure they meet specified standards; performing preventive maintenance; and calibrating measurement and testing equipment (Fig. 3.2). Prevention costs are typically planned and incurred before actual operations begin, with all funds spent before the product is even manufactured. By focusing on prevention, organizations can reduce the costs associated with poor quality. Examples of prevention costs encompass activities specifically designed to avoid subpar quality, such as addressing coding errors, design flaws, mistakes in user manuals, or overly complex and difficult-to-maintain code. Additional examples include the costs of new product development and review, quality planning, supplier capability assessments, process capability evaluations, quality improvement initiatives, and training and education in quality practices.

The Cost of Non-Conformance (CONC), also known as the Cost of Poor Quality (COPQ), refers to expenses incurred due to activities and processes that fail to meet agreed-upon performance standards or expected outcomes. These costs could be eliminated if every task were performed flawlessly without any deficiencies. CONC is further categorized into two components: **Cost of Appraisal**, which involves measuring and monitoring quality, and **Cost of Failure**, which includes costs resulting from defects or errors.

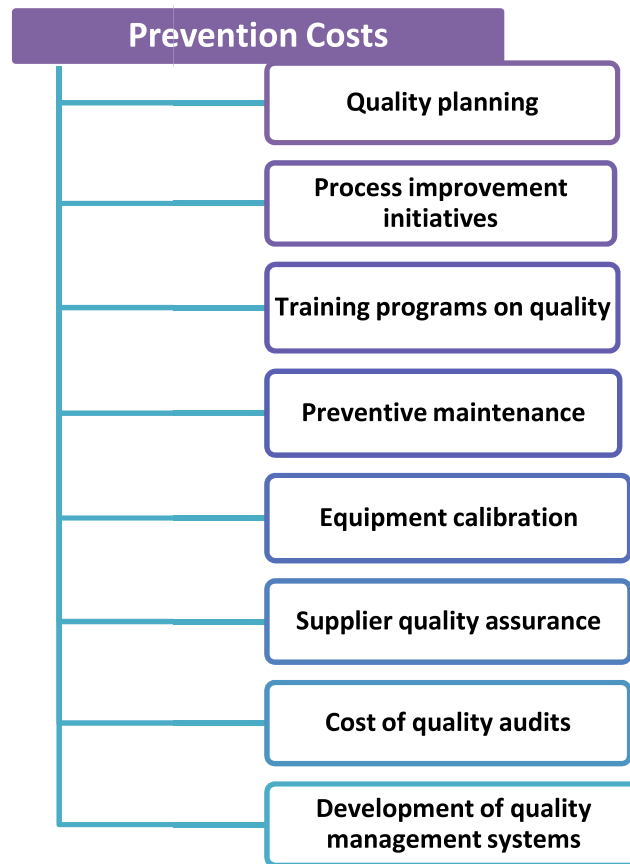


Fig. 3.2: Types of Prevention Costs

3.4.3 Appraisal Costs

Appraisal costs includes the expenses incurred in evaluating completed products to ensure they meet the required specifications before they are delivered to customers or moved to the client's location. These costs include activities such as inspections, testing, and reviews conducted after production but prior to shipment. Examples include inspecting finished goods, field testing, pre-dispatch inspections, and verifying shipping documents.

These costs are associated with testing and inspection processes aimed at identifying non-conforming products before they reach internal or external clients. As Vachette aptly defines, "appraisal costs represent all the expenses incurred to ensure a non-conforming product does not reach its customer." This category includes costs for inspecting and testing purchased materials and products, in-process and finished product inspections, acceptance tests, purchasing and maintaining testing equipment, conducting laboratory tests, documenting inspections and tests, wages for inspection and testing personnel, analyzing inspection and test results, and any materials or products destroyed during testing.

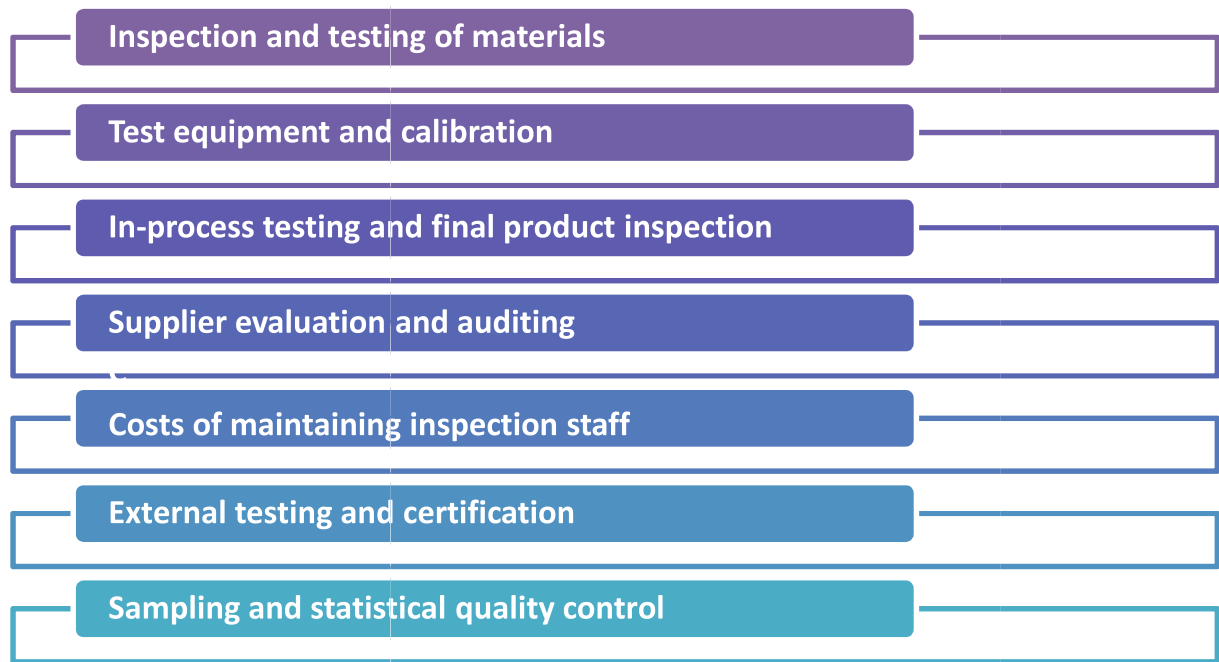


Fig. 3.3: Types of Appraisal Costs

3.4.4 Failure Costs

The Cost of Failure encompasses all expenses associated with defective products, whether identified before or after delivery to users. It is categorized into Internal Failure Costs and External Failure Costs.

Internal Failure Costs

These are the expenses associated with identifying and correcting defects or non-conformities before a product is shipped or delivered to customers. These costs arise when quality issues are detected during production or internal inspections and can significantly impact operational efficiency and profitability. For instance, Product/Service Design Failure Costs occur when a design flaw necessitates corrective actions, such as redesigning components, reworking prototypes, or scrapping products due to incompatible or faulty designs. Similarly, Purchasing Failure Costs include expenses related to rejecting defective materials from suppliers, replacing substandard components, or reworking rejected items. For example, a manufacturer may incur costs to replace faulty raw materials supplied by a vendor or to process the supplier's corrective actions.

In the production phase, Operations Failure **Costs** are prominent. These include expenses for troubleshooting issues, conducting root cause analyses, and repairing defects in products. For example, if a batch of electronic components fails to meet specifications, the costs of re-inspecting, retesting, and repairing the faulty units fall under this category. Additionally, products damaged during production may lead to scrap costs, while some items may need to be downgraded to meet lower standards, resulting in financial losses. Labor inefficiencies are also a significant part of internal failure costs, as resources are diverted to address quality issues rather than focusing on productive activities. Other examples include expenses for material review boards, documentation of failure incidents, and extra operational efforts to address defects. For instance, if a car manufacturer detects paint imperfections during final inspections, costs incurred to repaint vehicles, re-inspect the work, and dispose of wasted materials are all internal failure costs. These examples illustrate how such costs, although contained within the organization, can accumulate quickly and highlight the importance of proactive measures to prevent defects and ensure quality during the production process.

External Failure Costs

They refer to the expenses incurred when defects or non-conformities in products are identified after they have been shipped to customers or reached the market. These costs are often more damaging than internal failure costs as they directly impact customer satisfaction, brand reputation, and long-term business success. In the food industry, external failure costs include a wide range of expenses resulting from product recalls, customer complaints, warranty claims, legal liabilities, and damage to goodwill. For example, if a food company distributes a batch of packaged snacks that are later found to be contaminated due to improper hygiene during production, the company may face significant recall costs. These costs cover the logistics of pulling the defective products from retail shelves, disposing of the unsafe items, and reimbursing retailers or customers. Additionally, warranty claims arise when consumers demand refunds or replacements for spoiled, mislabeled, or defective food items. A dairy company, for instance, might incur warranty costs if customers return milk products found to have expired prematurely.

Another major component of external failure costs in the food industry is customer complaint handling and investigation. If a restaurant chain receives complaints about foodborne illnesses linked to their meals, the costs of investigating the complaints, responding to customers, and implementing corrective actions can be significant. Legal liabilities and penalties are also critical external failure costs. For instance, a food manufacturer may face lawsuits or regulatory fines if their products violate

food safety standards, such as the presence of allergens not disclosed on the label. Loss of goodwill and brand damage is an intangible but highly impactful external failure cost. A food company involved in a scandal such as an outbreak of *E. coli* traced to their processed meat can suffer long-term damage to its reputation, leading to reduced customer loyalty and lost sales. For example, a high-profile recall of contaminated baby food could lead to significant trust issues among parents, causing a decline in market share for years to come. In severe cases, external failure costs may also involve penalties from government agencies, such as fines imposed by the Food and Drug Administration (FDA) for non-compliance with safety regulations. Additionally, companies may incur costs for post-recall marketing campaigns aimed at restoring consumer trust and rebuilding their reputation. These examples highlight how external failure costs in the food industry extend far beyond immediate financial losses, emphasizing the critical need for stringent quality control measures to prevent such failures.

$$\text{Total Cost of Quality} = \text{Prevention} + \text{Appraisal} + \text{Internal Failure} + \text{External Failure}$$

Table 3.1: Internal Failure vs. External Failure Costs

Internal Failure Costs	External Failure Costs
Costs incurred due to defects identified before delivery to the customer.	Costs incurred due to defects identified after delivery to the customer.
Examples include: Rework or correction of defects Scrap and waste materials Downtime due to defects Failure during in-house testing	Examples include: Warranty claims Returns and replacements Legal liabilities Loss of reputation Customer complaints handling
Primarily affects operational efficiency and increases production costs.	Affects customer satisfaction, damages brand reputation, and can lead to revenue loss.
Identified during in-house processes, inspections, or quality checks.	Identified after the product/service reaches the customer.
Focused on improving internal processes	Focused on ensuring the final product/service meets

and quality control measures.	customer expectations.
Increases costs due to additional time and resources required to fix defects internally.	Results in higher costs due to refunds, penalties, loss of goodwill, and potential loss of future business.

3.5 MEASUREMENT OF QUALITY COSTS

Quality should be viewed as an investment, requiring financial accountability for all quality efforts. The true value of measuring the Cost of Quality (COQ) lies not in the act of measurement itself but in the analysis, comparison, and application of the data for monitoring, control, and strategic decision-making. Consistent application of COQ principles i.e. measurement, analysis, and corrective actions can lead to significant reductions in quality costs and drive continuous improvement.



Fig. 3.4: Measurement of Quality Costs

The Cost of Quality (COQ) model provides a visual representation of prevention, appraisal, and failure costs over time, effectively illustrating the impact of poor quality. The model operates on the principle that prevention is better than cure. By increasing investments in quality assurance and preventive

measures, the occurrence of failures can be significantly reduced, leading to a substantial decrease in total failure costs. When quality is fault-free, failure costs are eliminated, leaving the total cost of quality equal to the sum of quality assurance and prevention costs. This highlights the value of prioritizing quality assurance and prevention efforts, as these investments yield greater benefits by minimizing quality issues.

The COQ model also enhances understanding of the COQ metric and its components, which is critical for developing a comprehensive quality management strategy. This strategy not only improves the quality of products and services but also strengthens the organization's brand image. The concept is best visualized through a diagram that clearly illustrates the relationship between the various cost components.



Fig. 3.5: Cost of Quality (COQ) Model

3.6 IMPORTANCE OF QUALITY COSTS

The concept of quality costs is crucial for organizations aiming to achieve operational excellence and long-term sustainability. Quality costs provide a structured framework to identify, measure, and analyze the financial impact of activities related to maintaining and improving quality. Understanding these costs allows organizations to pinpoint inefficiencies, such as defects, rework, or warranty claims, and invest strategically in prevention and improvement efforts. By tracking quality costs, businesses can prioritize initiatives that not only enhance product or service quality but also

reduce waste, improve customer satisfaction, and protect brand reputation. Furthermore, the analysis of quality costs supports data-driven decision-making, enabling companies to allocate resources effectively, maximize return on investment, and align quality goals with broader organizational objectives. In essence, managing quality costs is not just about reducing expenses but also about fostering a culture of continuous improvement and driving competitive advantage.

The key benefits of managing quality costs effectively are:

- **Improved Product or Service Quality:** Focusing on quality costs helps organizations deliver superior products or services that meet or exceed customer expectations.
- **Reduced Waste and Rework:** Identifying inefficiencies through quality cost analysis minimizes defects, rework, and waste, leading to cost savings.
- **Enhanced Customer Satisfaction:** Consistently high quality builds trust and loyalty among customers, improving retention and market reputation.
- **Better Financial Performance:** Reducing failure costs and investing in prevention leads to lower overall costs and increased profitability.
- **Data-Driven Decision-Making:** Quality cost measurement and analysis provide actionable insights, enabling informed strategic decisions.
- **Competitive Advantage:** Consistently high quality differentiates the organization in the market, attracting more customers and boosting brand value.
- **Compliance and Risk Mitigation:** Effective quality management reduces the risk of regulatory penalties and legal issues due to non-conformance or defective products.
- **Support for Continuous Improvement:** Tracking and analyzing quality costs encourages a culture of ongoing refinement and innovation.
- **Resource Optimization:** Helps allocate resources efficiently by identifying the areas that yield the greatest impact on quality improvements.
- **Long-Term Sustainability:** Managing quality costs ensures business resilience by fostering trust, reducing operational risks, and maintaining financial health.

3.7 SUM UP

This unit has helped you to define and explain the components of quality costs, including prevention, appraisal, and failure costs. Learners will appreciate the role of managing quality costs in improving organizational efficiency and financial performance. Students will learn to distinguish between internal

and external failure costs and understand their implications on operations and customer satisfaction. Through this unit you were able to understand the principles of the COQ model and learn how to use COQ data to make informed strategic decisions regarding quality assurance and investments. The unit also fostered an understanding of measurement and analyzing quality costs effectively. Learners will grasp how to allocate resources effectively by investing in prevention and quality assurance for maximum benefit. Students will recognize how effective COQ management contributes to an organization's brand image, market competitiveness, and long-term sustainability.

3.8 CHECK YOUR PROGRESS

1. Define:

a) Cost

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b) Quality Cost

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c) Appraisal Cost

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d) Cost of Non conformance

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2. Differentiate between Internal and External failure costs.

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3. List the steps involved in measurement of Quality Cost.

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4. Explain the COQ model and its importance.

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5. List the benefits of managing quality costs effectively.

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मुक्त विश्वविद्यालय, प्रयागराज

MFN 117

FOOD SAFETY AND QUALITY CONTROL

BLOCK-2 PRODUCT EVALUATION, VARIOUS TESTS FOR RAW FOOD INGREDIENTS AND CONSUMER PROTECTION

Unit-4	INTRODUCTION TO FOOD SAMPLING	53
Unit-5	INTRODUCTION TO FOOD ANALYSIS	75
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BLOCK II - PRODUCT EVALUATION, VARIOUS TESTS FOR RAW FOOD INGREDIENTS AND CONSUMER PROTECTION

Product evaluation plays a crucial role in ensuring the quality, safety, and effectiveness of food products before they reach consumers. Regulatory bodies like the Food Safety and Standards Authority of India (FSSAI), Bureau of Indian Standards (BIS), and AGMARK establish guidelines for testing procedures to ensure that food products meet national and international safety standards. Block II consists of three units i.e. Unit IV which deals with introduction to food sampling; Unit V gives an introduction to food analysis and Unit VI delves into various food laws and regulations.

Unit IV gives an introduction to food sampling. Sampling is a crucial process in research, quality control, and decision-making, involving the selection of a subset from a population to derive meaningful conclusions. It enhances efficiency by saving time and resources while ensuring accuracy and representativeness. This unit covers sampling concepts, probability and non-probability sampling methods, sampling plans, sample preparation, and common errors. A clear understanding of these principles helps in designing effective sampling strategies across fields such as food safety, scientific research, healthcare, business analytics, and environmental studies.

Food analysis is essential in food science to ensure the quality, safety, and nutritional value of food products. Unit V explores various analytical methods, including physical, chemical, microbiological, and sensory evaluation. It covers the analysis of food components such as viscosity, specific gravity, texture, moisture, protein, fat, fiber, starch, sugar, and minerals using instrumental techniques. Microbiological methods like pour plate, MPN technique, ELISA, and PCR are also discussed. These techniques help detect adulteration, maintain consistency in food processing, and assess ingredient effects on food properties.

National food standards ensure the quality, safety, and reliability of products across industries. Unit VI examines the role and impact of national food standards. In India, regulatory bodies like BIS, AGMARK, and FSSAI set scientific benchmarks for manufacturing, labeling, and distribution to protect consumers and promote fair trade. These standards help maintain food safety, accurate measurements, and product certification. By fostering consumer trust and enhancing product quality, they contribute to public health, safety, and economic growth.

UNIT-IV INTRODUCTION TO FOOD SAMPLING

Structure

- 4.1 Introduction
- 4.2 What is Sampling?
- 4.3 Importance of Sampling
- 4.4 Key Concepts in Sampling
- 4.5 Sampling Techniques
 - 4.5.1 Probability Sampling
 - 4.5.2 Non Probability Sampling
- 4.6 Sampling Plan
- 4.7 Preparation of Samples
- 4.8 Errors in Sampling
- 4.9 Sum Up
- 4.10 Check your Progress

4.1 INTRODUCTION

Sampling is a fundamental process in research, quality control, and decision-making that involves selecting a subset of a population to draw conclusions about the whole set. It allows researchers and professionals to analyze data efficiently, saving time and resources while ensuring accurate and representative results. The effectiveness of a study or analysis largely depends on the sampling method used, making it essential to understand the different types of sampling techniques, their applications, and potential errors. This chapter explores sampling concepts, probability and non-probability sampling methods, sampling plans, sample preparation, and common errors in sampling. By understanding these principles, students can make informed choices about planning and conducting sampling strategies in fields such as food safety, scientific research, healthcare, business analytics, and environmental studies.

Objectives

After learning this unit, you will be able to:

- define sampling
- understand the importance of sampling
- explain the key concepts of sampling
- differentiate between sampling techniques
- develop a sampling plan
- explain the sample preparation process
- identify various sampling errors and their causes
- find methods to reduce sampling errors

4.2 WHAT IS SAMPLING?

To maintain food quality and ensure it meets acceptable standards, it is important to check key features of raw materials, ingredients, and processed foods. If testing is fast and does not damage the product, every item in a batch can be examined. However, in most cases, it is more practical to test only a small part of the batch and assume it represents the whole. This process is called sampling, and the entire batch from which the sample is taken is known as the population. A good sampling method ensures that test results accurately reflect the quality of the entire batch. By testing only a portion instead of everything, quality checks become quicker, more cost-effective, and still reliable. Although a sample provides an estimate rather than an exact measurement of the population, proper sampling methods enhance its accuracy and reliability.

Sampling is the process of selecting a subgroup of items from a large population to analyze and draw conclusions about the whole. It is widely used in various fields, including quality control, research, and statistics, to assess characteristics, detect defects, and ensure compliance with standards without examining every individual unit. In the food industry, sampling is crucial for quality assurance and safety testing, ensuring that products meet regulatory and consumer expectations. Proper sampling methods help in detecting contaminants, verifying ingredient composition, and maintaining consistency in production.

4.3 IMPORTANCE OF SAMPLING

Food sampling is a critical practice in quality assurance, ensuring that food products meet safety, regulatory, and consumer expectations. By analyzing a representative portion of a batch, food manufacturers and regulatory agencies can assess quality, detect contaminants, and ensure compliance

with industry standards. The reliability of analytical data depends on several factors, with sampling being the most crucial. Modern analytical methods require only a small quantity of food, often just a few grams for testing. To enhance the overall quality of the analytical process, laboratories should strive to receive well-documented, representative, and defensible samples. Therefore, it is essential that the selected sample accurately represents the entire population. Developing effective sampling plans requires an understanding of the challenges involved in each stage and applying sound judgment to address them.

Importance of Food Sampling:

- **Ensures Food Safety:** It helps in detecting harmful contaminants such as bacteria, toxins, pesticides, and heavy metals. It also prevents foodborne illnesses by identifying unsafe products before they reach consumers.
- **Maintains Product Quality:** Ensures consistency in taste, texture, color, and nutritional content and also helps in maintaining uniformity across different batches of production.
- **Regulatory Compliance:** Ensures adherence to national and international food safety standards (e.g., HACCP, Codex Alimentarius, ISO 22000). Thus helps businesses meet government regulations and avoid legal consequences.
- **Reduces Costs and Waste:** It prevents large-scale product recalls by identifying defects early in production. Reduces financial losses by catching issues before full-scale distribution.
- **Enhances Consumer Confidence:** Builds trust by ensuring high-quality, safe, and reliable food products thereby strengthening brand reputation and customer loyalty.
- **Supports Research and Development:** Helps in developing new food products by analyzing ingredient interactions. Also assists in refining production processes for better efficiency and quality control.
- **Improves Shelf Life and Storage Conditions:** Ensures proper formulation and packaging to enhance product longevity. Helps to monitor stability and microbial growth over time.

Therefore, effective food sampling can help businesses to maintain high standards while protecting consumer health and meeting regulatory requirements.

4.4 KEY CONCEPTS IN SAMPLING

To ensure clarity and precision in sampling theory, several fundamental concepts are outlined. These concepts form the foundation of sampling theory and are essential for designing effective sampling strategies. The key concepts are given as below:

- **Sampling Units and Population:**

A sampling unit refers to a well-defined and identifiable element or a group of elements from which data is collected. The entire collection of these units is called the population. If the population consists of a finite number of units, it is considered finite. For sampling purposes, the population is divided into smaller, manageable sampling units, where each elementary unit belongs to a single sampling unit.

- **Sampling Frame:**

A sampling frame is a complete list of all sampling units, along with their identification details and locations. It serves as the basis for selecting a sample. An ideal sampling frame should be up-to-date, free from errors, and without omissions or duplications.

- **Sample:**

A sample is a subset of the population selected for study. The number of sampling units included in the sample is called the sample size.

- **Sampling Fraction:**

The sampling fraction represents the proportion of the population included in the sample and is calculated as n/N , where n is the sample size and N is the total population size.

- **Sampling Procedure/Method:**

The sampling procedure refers to the technique used to select a sample from the population. This can be done using probability or non-probability sampling methods.

- **Census:**

A census involves collecting data from every unit within the population, ensuring complete enumeration. Unlike sampling, a census provides comprehensive and precise information about the entire population.

- **Population Parameter and Sample Estimator:**

A population parameter is any function of the population values, such as the population mean or variance. These values remain constant for a given population. A sample estimator (or statistic) is a function derived from the sample, such as the sample mean or variance. Unlike population parameters, these values vary from sample to sample, making them random variables.

4.5 SAMPLING TECHNIQUES

Sampling techniques are essential for ensuring that food quality assessments provide reliable and representative results. The choice of a sampling method depends on factors such as the type of food product, production process, and the purpose of analysis (e.g., microbiological, chemical, or sensory testing). Below are the commonly used sampling techniques:

4.5.1 Probability sampling

It is a method of sampling where every unit in the population has a known, non-zero chance of being selected. This method ensures that each sample is chosen randomly, and it reduces bias in the selection process. As a result, probability sampling allows for the generalization of results from the sample to the entire population, making it statistically valid and reliable. In probability sampling, the sample size can be determined based on the desired level of precision and confidence, which is particularly useful for large populations. There are several different types of probability sampling, each with its own application and benefits.

1. Simple Random Sampling

Simple random sampling ensures that every individual in a population has an equal chance of being selected, with each selection being independent of the others. This method eliminates bias and provides a fair representation of the entire population. Two commonly used techniques for simple random sampling are Lottery method and Random Number table method.

- **Lottery Method**

In this method, each member of the population is assigned a unique identifier. For instance, if we need to select a sample of 25 students from a total of 600 students in a college, we follow the following steps:

- Write the names or numbers of all 600 students on separate slips of paper.
- Place the slips in a container and mix them thoroughly.

- Randomly draw 25 slips, ensuring that each student has an equal probability of selection (1/600).
- Repeat the process until the desired sample size is reached.

This method is simple and effective, especially for small populations, but can be time-consuming for larger groups.

- **Random Number Table Method**

A random number table is a pre-generated list of numbers arranged in rows and columns, which is used to randomly select samples from a population. These tables contain sequences of digits (0-9) that are generated without any pattern, ensuring that each selection is purely random and unbiased. The steps are as follows:

- Each individual or unit in the population is assigned a unique number.
- Example I - There are 600 students, they can be numbered 001 to 600.
- Open a random number table and randomly select a row and column as the starting point.
- Since our population size is 600 (three-digit numbers), we take three-digit numbers from the table.
- Move horizontally or vertically across the table, reading the numbers sequentially.
- Ignore numbers that are out of the population range (i.e., greater than 600) and skip repeated numbers to avoid selecting the same individual twice.
- Repeat the process until the required sample size (e.g., 25 students) is obtained.

Example II: Selecting 5 Students from a Population of 50 using a random number table

Row/Col	1	2	3	4	5	6	7	8	9	10
1	07	42	15	63	89	02	30	46	21	50
2	11	09	58	33	75	19	41	04	23	49
3	27	55	60	45	32	10	08	37	01	39

- Suppose we start at Row 1, Column 1 and move horizontally.
- The first five numbers in our range (01-50) are 07, 42, 15, 02, 30. These correspond to the randomly selected students.

- Number like 63, 89 are omitted as they are out of the population range.

In modern applications, instead of using a printed random number table, a computerized random number generator (such as in Excel, Python, or R) can automate the process, making it faster and error-free.

2. Systematic Random Sampling

It is a method where samples are selected at regular intervals from an ordered population list. It is an efficient alternative to simple random sampling, especially when dealing with large populations, as it ensures even distribution of samples across the entire dataset. Steps to design a Systematic Random Sample are as follows:

- List all members of the population in a sequential manner.
- Example: If there are 1,000 employees in a company, list them from 1 to 1,000.
- Decide how many samples need to be selected.
- Example: If we need 100 employees from a 1,000-person company, the sample size (n) is 100.
- Calculate the Sampling Interval (k) using the formula:

$$k = \frac{\text{Population Size (N)}}{\text{Sample size (n)}}$$

For example,

$$k = \frac{1000}{100} = 10$$

This means every 10th person will be selected.

- Choose a random number between 1 and k (1-10) as the starting point. Example: If 7 is randomly chosen, the first selection will be the 7th individual.
- Continue adding the sampling interval (k) to the starting point to select additional samples. Example: If the starting point is 7, the selected individuals will be: 7, 17, 27, 37, 47, 57, ... 997.

Systematic Random Sampling requires selecting only the first random number, making it easier than pure random sampling. The samples are spread uniformly across the population. Since selection is systematic, it avoids personal judgment errors. However hidden patterns can affect randomness i.e.

if the population follows a pattern matching the sampling interval (e.g., a factory checks every 10th product, but defects occur every 10th item), the results may be misleading. Moreover if the population is unevenly distributed, this method might not provide a fully representative sample.

3. Stratified Random Sampling:

Stratified random sampling is a probability sampling method in which the population is divided into distinct subgroups, called strata, based on specific characteristics. A random sample is then taken from each stratum to ensure representation of all groups. This method improves accuracy and ensures that important subgroups are not underrepresented in the sample. The steps to conduct Stratified Random Sampling are as follows:

- Identify the entire population that needs to be studied. Example: A university with 10,000 students, where students are categorized by academic year (1st, 2nd, 3rd, and 4th year).
- The population is divided into strata based on a meaningful characteristic (e.g., age, gender, income level, education, region). Example: The university population can be divided as: 1st-year students; 2nd-year students; 3rd-year students and 4th-year students.
- Decide how many individuals should be sampled from the entire population. Example: If we need 400 students out of 10,000, the total sample size is $n = 400$.
- Determine the sample size for each stratum. There are two ways to allocate the sample across strata:

a) Proportional Stratified Sampling

Each stratum's sample size is proportional to its share of the population:

$$n_i = \frac{N_i}{N} \times n$$

Where:

n_i = Sample size for each stratum

N_i = Population size of each stratum

N = Total population size

n = Total sample size

Example:

If the university has students distributed as follows:

- 1st Year: 4,000 students (40%)
- 2nd Year: 3,000 students (30%)
- 3rd Year: 2,000 students (20%)
- 4th Year: 1,000 students (10%)

The sample is allocated proportionally:

- 1st Year: $\frac{4000}{10000} \times 400 = 160$ students
- 2nd Year: $\frac{3000}{10000} \times 400 = 120$ students
- 3rd Year: $\frac{2000}{10000} \times 400 = 80$ students
- 4th Year: $= \frac{1000}{10000} \times 400 = 40$ students

b) **Equal Stratified Sampling**

Each stratum receives the same number of samples, regardless of its size. If we decide to take 100 students from each year, the sample would be:

- 1st Year: 100 students
- 2nd Year: 100 students
- 3rd Year: 100 students
- 4th Year: 100 students

(Total Sample = 400)

- Conduct random sampling within each stratum using simple random sampling or systematic sampling to select individuals from each stratum. Example: If we need 160 students from the 1st year, use a random number table or a lottery method to pick students randomly from a list of 1st-year students.

In Stratified Random Sampling all subgroups are included, avoiding over or under representation. It reduces sampling error by accounting for differences between groups and works well when populations vary significantly in characteristics.

This sampling technique is more precise than simple random sampling, especially for heterogeneous populations.

4. Cluster Sampling

Cluster sampling is a probability sampling method in which the population is divided into naturally occurring groups, called clusters, and then a random selection of clusters is made. Instead of selecting individuals randomly from the entire population, entire clusters are selected, and all individuals within those clusters are studied. This method is particularly useful for large, geographically dispersed populations where simple or stratified random sampling would be difficult and expensive to implement.

Types of Cluster Sampling

1. Single-Stage Cluster Sampling

- The entire population is divided into clusters.
- A random selection of clusters is made.
- All individuals within the selected clusters are included in the sample.

Example:

A national education survey wants to assess student performance in high schools across a country. The country is divided into districts (clusters). Five districts are randomly selected and all students in the selected districts are included in the study.

2. Two-Stage Cluster Sampling

- The population is divided into clusters.
- A random selection of clusters is made.
- Instead of selecting all individuals, a random sample is taken from within the selected clusters.

Example:

A healthcare study aims to evaluate nutrition levels among schoolchildren in a state. Thus the state is divided into school districts (clusters). Ten districts are randomly selected and within each selected district, only 50 students are randomly chosen for the study.

3. Multistage Cluster Sampling

- The population is divided into clusters.
- A random selection of clusters is made.
- Within the selected clusters, sub-clusters are formed, and further random selection occurs.
- This process continues through multiple stages until the final sample is selected.

Example:

A government study aims to assess household income across a country. The country is divided into states (clusters). Five states are randomly selected and within each state, 3 cities are randomly chosen. Further within each city, 10 neighborhoods are randomly picked. Finally, 20 households from each selected neighborhood are surveyed.

Cluster Sampling is cost-effective and time saving as it reduces travel, administrative, and research costs. It is suitable for nationwide or regional studies. It is found to be simpler than simple or stratified random sampling when dealing with dispersed groups. However, since clusters may be homogeneous, results may be less precise than simple random sampling and if clusters are not truly representative, results may be skewed.

4.5.2 Non Probability Sampling

A non-probability sample is one where cases are selected in a way that provides information about the sample itself but does not guarantee equal chances of selection for all individuals in the population. While findings from such samples can be generalized to the population to some extent, they do not have the statistical precision of probability sampling. This type of sampling is also known as purposive sampling and is widely used in market surveys, opinion research, and behavioral studies to understand attitudes, reactions, and consumer preferences. Several types of non-probability sampling exist, including snowball sampling, convenience sampling, judgment (purposive) sampling, and quota sampling.

1. Convenience Sampling

Convenience sampling involves selecting participants who are readily available and easy to contact, making data collection quick and cost-effective. Researchers or interviewers approach individuals based on accessibility rather than a structured selection process. Participants are chosen

because they are in a specific location or readily willing to participate. Example: A researcher conducting a survey at a shopping mall interviews shoppers who happen to be present, without a predefined selection process.

2. Judgment (Purposive) Sampling

Judgment sampling, also known as purposive sampling, involves selecting participants based on the researcher's knowledge and expertise about the population. The chosen individuals are expected to best represent the characteristics being studied. The researcher intentionally selects individuals who fit specific criteria. This method is commonly used when the target population has unique characteristics. Example: A company launching a new fitness product specifically targets health-conscious individuals and gym-goers for feedback, rather than randomly surveying the general public.

3. Quota Sampling

Quota sampling is a non-probability sampling technique that is similar to stratified sampling. In this method, the population is divided into specific categories (strata) based on certain characteristics, and a predetermined number of samples (quota) is selected from each category. However, unlike stratified random sampling, selection within each stratum is non-random and based on researcher discretion. The researcher defines key population categories (e.g., age, gender, occupation). Each category is assigned a quota, meaning a fixed number of participants must be selected. The researcher actively selects individuals within each quota until the required sample size is met. Example: A company conducting a survey on customer satisfaction in a city may set the following quotas as 50% male, 50% female respondents or as 25% students, 50% working professionals, 25% retirees. Once the quota for each category is filled, no further samples are taken from that category. Quota Sampling is done when we need a diverse but structured sample (e.g., age, gender, occupation) or while conducting market research or public surveys with limited time and resources for data collection.

4. Snowball Sampling

Snowball sampling is a network-based sampling method where existing participants recruit new participants from their social or professional circles. This creates a chain-referral process that continues until the desired sample size is achieved. The researcher identifies a few initial participants (seeds) who fit the study criteria. These participants refer others they know who also meet the criteria. The process continues expanding (like a snowball rolling and growing in size) until the required

number of participants is reached. Example: A study on drug addiction recovery might begin with 5 recovered individuals. They refer 10 more recovering individuals from their support groups. These 10, in turn, refer others, and the sample grows like a chain. It can be used in research on hidden populations (e.g., undocumented workers, refugees), studies on rare diseases where participants are hard to find or for social networking studies to map relationships and connections. Table 4.1 outlines major differences in various types of non probability sampling.

Table 4.1: Types of Non-Probability Sampling

Feature	Convenience Sampling	Judgment Sampling	Quota Sampling	Snowball Sampling
Selection Basis	Availability and ease of access	Researcher's expertise and judgment	Predefined quotas based on characteristics	Participants refer others in their network
Randomization	No random selection	No random selection	No random selection	No random selection
Best For	Quick and exploratory research	Targeted research, forecasting, and case studies	Market research, public opinion polls	Research on hidden or hard-to-reach populations
Potential Bias	High (not representative)	Moderate (depends on researcher's selection)	Moderate (ensures diversity but still non-random)	High (may over represent certain social groups)
Cost & Time	Low cost, quick	Moderate cost, takes time to find qualified participants	Low cost, quick to implement	Low cost, but takes time to expand the sample

Data Reliability	Low	Moderate	Moderate	Low to moderate
	A food company surveys customers in a supermarket	A health study selects nutritionists to discuss diet trends	A political survey ensures proportional representation of age groups	Research on undocumented workers where one participant refers others
Example	Interviewing shoppers in a mall	Selecting industry experts for a technology survey	Ensuring a survey has 50% male and 50% female respondents	A study on drug addiction where participants refer others from their support group

4.6 SAMPLING PLAN

A sampling plan is a structured approach that outlines how a sample will be selected from a population for study or quality assessment. It specifies what, how, when, and how much data will be collected to ensure reliable and representative results. Sampling plans are crucial in research, manufacturing, food safety, healthcare, and quality control processes. The key components of a sampling plan are:

- **Define the objective of Sampling:** Define the purpose of the sampling process eg. to assess food quality, inspect product defects, or measure customer satisfaction. Table 4.2 gives an outline of a sampling plan for a food quality inspection.
- **Identify Target Population:** Identify the population from which the sample will be drawn eg. all food products produced in a factory in a given month.
- **Select Sampling Frame:** Prepare a list or database that includes all the units in the population eg. a batch record of all processed food items.
- **Select Sampling Method:** Choose a sampling technique (Probability or Non-Probability).
 - Probability Sampling Methods:
 - Simple Random Sampling
 - Systematic Sampling

- Stratified Sampling
 - Cluster Sampling
- Non-Probability Sampling Methods:
 - Convenience Sampling
 - Judgmental (Purposive) Sampling
 - Quota Sampling
 - Snowball Sampling
- **Determination of Sample Size:** Decide how many units will be included in the sample. It will be decided using the formula for selected sampling technique.
- **Define Sampling Procedure:** Define step-by-step instructions on how to select the sample. Example: In a food quality check, select every 20th packaged product from the production line.
- **Select Data Collection Methods:** Specify the methods for data collection like Direct Observation; Surveys & Questionnaires; Laboratory Testing or Sensor-Based Measurement.
- **Define Acceptance Criteria:** Define the thresholds or quality standards to determine whether a sample meets or fails requirements eg. a food product should contain less than 1% foreign material to pass inspection.
- **Analysis & Reporting:** Specify how data will be analyzed, reported, and interpreted. For example: Defects will be categorized into minor, major, and critical, and corrective actions will be recommended.
- **Review and Adjustment:** Sampling plans should be reviewed periodically and updated based on findings and quality improvements.

Table 4.2: Sampling plan for Food Quality Inspection

Component	Details
Objective	Check contamination in dairy products.
Target Population	Milk products from 5 dairy plants.
Sampling Frame	Production batches from January to March.
Sampling Method	Stratified Random Sampling (based on production batches).
Sample Size	50 samples per plant (Total = 250).
Sampling Procedure	Randomly pick 50 packaged milk cartons per plant.

Data Collection	Laboratory testing for microbial contamination.
Acceptance Criteria	Bacterial count <10,000 CFU/mL is acceptable.
Analysis	Compare results with industry standards and report deviations.

4.7 PREPARATION OF SAMPLES

Sample preparation is a critical process in research, quality control, and laboratory analysis, ensuring that the collected sample is representative, reliable, and suitable for testing. It involves a series of well-defined steps to handle, preserve, and condition the sample while minimizing contamination, degradation, or alteration. The process begins with sample collection, where materials are carefully gathered following standardized procedures to avoid bias. Depending on the nature of the sample, (whether solid, liquid, or gas), different collection techniques are employed, such as aseptic techniques for microbiological samples or sterile sampling for food safety testing. Once collected, sample handling and transportation are crucial to maintaining integrity; proper labeling, temperature control, and contamination prevention are key aspects at this stage. For instance, perishable food samples may require refrigeration, while chemical samples might need airtight containers to prevent oxidation.

Following transportation, sample preservation and storage are implemented to prevent physical, chemical, or microbial deterioration. Common preservation methods include freezing, refrigeration, vacuum sealing, and the use of chemical stabilizers. For example, biological samples such as milk require cold storage to inhibit bacterial growth, while powdered samples like flour should be stored in moisture-free environments to prevent clumping. After preservation, sample homogenization ensures uniformity, particularly in heterogeneous samples like food mixtures, water, or soil. Techniques such as grinding, blending, shaking, or ultrasonic dispersion help achieve consistency in composition, making the sample more representative for testing.

In many cases, sample reduction (sub-sampling) is required to extract a manageable portion while maintaining representativeness. Techniques such as coning and quartering (used for granular samples like grains or powders) or pipetting (for liquid samples) are applied to ensure fair distribution of sample components. The next phase involves sample preparation for specific analysis, depending on the type of test being conducted. Microbiological testing may require serial dilution and plating on culture media, chemical analysis may involve solvent extraction or filtration, and physical testing

might need sieving or drying. For example, food safety laboratories often blend solid samples into homogenized solutions before testing for pesticide residues or contaminants.

Quality control is a key aspect of sample preparation, ensuring that every step adheres to regulatory standards and minimizes errors. Calibrated instruments, properly trained personnel, and strict adherence to laboratory protocols help maintain accuracy and reproducibility. Finally, proper documentation and standardization ensure that sample preparation methods are traceable and repeatable across different testing environments. In industries such as food safety, pharmaceuticals, and environmental science, precise sample preparation is essential for producing valid and reliable results that support decision-making, regulatory compliance, and product quality assurance.

4.8 ERRORS IN SAMPLING

Sampling errors occur when a sample does not perfectly represent the entire population, leading to inaccuracies in conclusions drawn from the data. These errors can arise due to faulty sampling techniques, improper data collection, or natural variations within the population. Sampling errors are broadly classified into two main categories:

1. **Random Sampling Errors** (Statistical errors due to chance)
2. **Non-Sampling Errors** (Systematic errors due to biases or mistakes)

4.8.1 Random Sampling Errors

These errors occur naturally because only a portion of the population is sampled instead of the whole. They are unavoidable but can be minimized by increasing the sample size or using better sampling techniques. Random Sampling Errors may be caused either due to selecting a small sample size, leading to poor representation or variability in the population, making it difficult to capture all characteristics. Imperfect randomization, where chance alone creates imbalance can also cause such errors. Example: A survey on customer satisfaction selects 100 customers out of 10,000. If most of the selected customers are regular buyers, their responses may not fully represent the opinions of occasional buyers. Random Sampling Errors can be minimized by increasing sample size to capture more variation; using stratified or systematic sampling instead of simple random sampling and ensuring truly random selection to prevent bias.

4.8.2 Non-Sampling Errors

These errors arise from mistakes in the sampling process, data collection, or human bias. Unlike random errors, these are systematic and can often be avoided. Table 4.3 highlights the differences between random sampling errors and non sampling errors.

Types of Non-Sampling Errors:

a) Selection Bias (Sampling Bias): Occurs when certain groups in the population are overrepresented or underrepresented due to a flawed sampling method. Example: conducting an online survey about internet access only among urban residents, ignoring rural populations.

b) Non-Response Bias: Occurs when a significant number of selected participants do not respond, making the sample unrepresentative. Example: a telephone survey about political preferences may miss people who are too busy to answer or refuse to participate.

c) Measurement Error (Response Bias): Occurs when the data collected is inaccurate due to faulty measurement tools, misleading questions, or respondent dishonesty. Example: a diet survey asking participants about their eating habits may lead to underreporting of unhealthy food intake due to social desirability bias.

d) Processing Error (Data Entry & Analysis Mistakes): Occurs when errors occur while recording, entering, or analyzing data. Example: a research assistant mistakenly enters 65 instead of 56 in a dataset, skewing statistical results.

e) Coverage Error (Frame Bias): Occurs when the sampling frame does not include the entire target population. Example: A survey on employee satisfaction conducted only among full-time employees, excluding part-time or contract workers.

Table 4.3: Random vs. Non-Sampling Errors

Type of Error	Cause	Solution	Example
Random Sampling Error	Small sample size or chance variations	Increase sample size, use stratified sampling	Selecting 50 students to represent an entire university
Selection Bias	Unrepresentative sample	Ensure all groups are	Surveying only young

	selection	included in the sample	people for a mobile phone study
Non-Response Bias	Participants refuse or fail to respond	Follow up with reminders or offer incentives	Many people ignore online feedback surveys
Measurement Error	Faulty survey questions, inaccurate measurements	Use standardized and neutral wording	Asking leading questions about customer satisfaction
Processing Error	Data entry or calculation mistakes	Double-check data entry and use validation tools	Entering "25" instead of "52" in research data
Coverage Error	Incomplete sampling frame	Ensure complete and accurate population lists	Surveying only registered voters while studying political opinions

4.9 SUM UP

After completing this unit, you will be able to understand the Fundamentals of Sampling and Gain knowledge of key concepts such as population, sampling units, sampling frames, and sample selection. The unit helped you to identify and explain different types of probability and non-probability sampling techniques. You learnt how to design an effective sampling plan, including determining sample size, choosing appropriate sampling techniques, and ensuring proper execution. The unit also helped you understand the procedures involved in sample collection, handling, preservation, homogenization, and reduction to ensure accurate and reliable testing. Through this unit you also learnt to distinguish between random and non-sampling errors, their causes, and how to minimize them to improve the reliability of results. By understanding these concepts, the student will be equipped with the necessary skills to implement effective sampling strategies in research and industry applications.

4.10 CHECK YOUR PROGRESS

1. Define:

a) Sampling

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b) Population

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c) Sampling Fraction

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d) Sampling Estimator

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2. Explain simple random sampling with suitable examples.

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3. Explain different types of stratified random sampling.

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4. What is cluster sampling? Explain its types briefly.

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5. Differentiate between convenience and judgment sampling.

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6. Explain the steps involved in a sampling plan.

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7. List the various errors caused in sampling.

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UNIT-V INTRODUCTION TO FOOD ANALYSIS

Structure

5.1 Introduction

5.2 Food Analysis

5.3 Physical Analysis

5.3.1 Colour

5.3.2 Specific Gravity

5.3.3 Viscosity

5.3.4 Particle Size

5.3.5 Water Activity

5.3.6 Texture Analysis

5.4 Chemical Analysis

5.4.1 Moisture Analysis

5.4.2 Protein Estimation

5.4.3 Fat Analysis

5.4.4 Fibre Content

5.4.5 Ash Content

5.4.6 Reducing and Non Reducing Sugars

5.4.7 Starch Content

5.5 Microbiological Analysis

5.5.1 Pour Plate Method

5.5.2 Membrane Filtration Method

5.5.3 Most Probable Number (MPN) Technique

5.5.4 Enzyme-Linked Immunosorbent Assay (ELISA)

5.5.5 Polymerase Chain Reaction (PCR)

5.6 Sensory Analysis

5.7 Sum Up

5.8 Check your Progress

5.1 INTRODUCTION

Food analysis is a crucial aspect of food science, ensuring the quality, safety, and nutritional value of food products. This unit provides an in-depth understanding of different analytical methods, including physical, chemical, microbiological and sensory evaluation. It involves the systematic evaluation of food components such as viscosity, specific gravity, texture analysis, moisture, protein, fat, fiber, starch, sugar and minerals using various instrumental methods. The unit also deals with various microbiological techniques like pour plate method, MPN technique, ELISA and PCR. The techniques used in food analysis help detect adulteration, ensure consistency in food processing, and assess the impact of ingredients on food properties.

Objectives

After learning this unit, you will be able to:

- understand the importance of food analysis
- explain key analytical methods
- discuss analysis of physical parameters
- understand principles of proximate analysis
- explain the analysis of sugars and starch
- list different microbiological analytical methods
- define sensory analysis and its importance
- explain sensory tests used in food analysis

5.2 FOOD ANALYSIS

Food analysis is the process of evaluating the composition, quality, safety, and nutritional value of food products using physical, chemical, and microbiological methods. It plays a crucial role in quality control, regulatory compliance, food safety assessment, and product development. Physical analysis examines texture, color, specific gravity, viscosity, and density, ensuring consistency and consumer appeal. Chemical analysis focuses on nutritional composition, pH levels, fat, protein,

carbohydrates, vitamins, minerals, and contaminants such as pesticides and heavy metals. Microbiological analysis detects harmful bacteria, yeast, mold, and toxins to prevent foodborne illnesses. These analytical techniques help food manufacturers maintain product safety, authenticity, and compliance with regulatory standards such as FDA, FSSAI, Codex Alimentarius, and ISO 22000. By ensuring food quality and safety, food analysis protects public health and enhances consumer confidence in food products.

Importance of Food Analysis

Food analysis is essential for ensuring the safety, quality, authenticity, and nutritional value of food products. It plays a critical role in public health, regulatory compliance, and food industry operations. The key reasons why food analysis is important include:

1. **Ensures Food Safety** – Detects contaminants such as pesticides, heavy metals, toxins, and microbial pathogens that can cause foodborne illnesses.
2. **Maintains Nutritional Quality** – Verifies the presence of essential nutrients like **proteins, carbohydrates, fats, vitamins, and minerals**, ensuring accurate labeling and consumer awareness.
3. **Regulatory Compliance** – Helps food manufacturers meet national and international food safety standards (e.g., FDA, FSSAI, Codex Alimentarius, ISO 22000) to prevent legal issues and product recalls.
4. **Prevents Food Fraud** – Identifies adulteration, mislabeling, and substitution in food products (e.g., detecting synthetic dyes in spices or water adulteration in milk).
5. **Improves Shelf Life & Quality Control** – Evaluates factors like moisture content, pH, texture, and oxidation to ensure products remain stable and fresh over time.
6. **Supports Consumer Confidence** – Assures consumers that food products are safe, nutritious, and meet expected quality standards, enhancing brand trust.
7. **Aids in Product Development** – Helps food manufacturers develop new formulations, improve taste, texture, and nutritional content, and ensure product consistency.

5.3 PHYSICAL ANALYSIS

Physical analysis of food involves the evaluation of the structural, mechanical, and sensory properties of food products. These tests assess characteristics such as texture, color, particle size,

viscosity, and density, which impact food quality, stability, and consumer acceptance. Physical analysis is crucial in food processing, quality control, and product development, ensuring consistency and compliance with industry standards.

5.3.1 Colour

Colour is a critical attribute in food analysis as it directly influences consumer perception, quality control, and product acceptance. The appearance of food products is often the first factor that affects purchasing decisions. Consistent colour ensures uniformity, freshness, and adherence to industry standards. Measuring food colour scientifically eliminates subjective biases and ensures that food products meet regulatory requirements and consumer expectations. Colour in food is measured using two primary approaches:

1. **Instrumental (Objective) Methods** which use scientific devices to analyze colour.
2. **Sensory (Subjective) Methods** which involve visual assessment by trained analysts.

- **Munsell Colour System**

The Munsell Colour System classifies colour based on three attributes: hue (colour type), chroma (intensity), and value (lightness or darkness). Food samples are visually compared to a Munsell colour chart, which contains predefined colour shades. This method is commonly used in grading coffee beans, tea leaves, and flour. While easy to use, the method is subjective and prone to human error, requiring trained panelists for consistency.

- **Colorimetry (Tristimulus Method)**

Colorimetry is based on the three primary colours (Red, Green, and Blue - RGB), mimicking human vision. A colorimeter measures the amount of light absorbed and reflected by a food sample and converts it into L , a , b^* values** (lightness, red-green, yellow-blue). This method is widely used in tomato paste, fruit juices, and bakery products to ensure colour consistency.

- **Spectrophotometry (CIELAB System & UV-Vis Analysis)**

Spectrophotometry measures colour by analyzing how much light is absorbed or transmitted at different wavelengths. The *CIELAB system* (L , a , b) is the most commonly used spectrophotometric model, where L represents lightness, a represents red-green, and b represents yellow-blue components.

This method provides precise and repeatable results, making it ideal for analyzing dairy products, edible oils, beer, and sauces.

- **Digital Image Analysis (Computer Vision Systems)**

Computer vision systems use high-resolution cameras and software to capture and analyze food colour. The software processes the image to measure colour distribution, uniformity, and defects. This method is widely used in grading fruits, vegetables, and meat products. It eliminates human bias and provides high-speed analysis in industrial food processing.

- **Visual Inspection (Sensory Evaluation)**

Sensory evaluation involves trained panelists visually assessing the colour of food products under controlled lighting conditions. This method is commonly used in grading tea, coffee, and fresh produce. However, human perception can be inconsistent, making it less reliable than instrumental methods.

5.3.2 Specific Gravity

It is the ratio of the density of a food sample to the density of water at a given temperature. It is a crucial physical property used to determine the composition, quality, and consistency of liquid and semi-solid food products. Since the density of water is 1 g/cm³ (at 4°C), specific gravity is dimensionless and represents how much heavier or lighter a substance is compared to water.

$$\text{Specific Gravity} = \frac{\text{Density of food sample (g/cm}^3\text{)}}{\text{Density of water at same temperature (g/cm}^3\text{)}}$$

Methods for Measuring Specific Gravity

1. Pycnometer Method (Density Bottle Method): This method compares the weight of a known volume of a liquid sample to the weight of an equal volume of water. For example measuring the specific gravity of milk to detect dilution or excess fat content.
Procedure:

- Weigh the empty pycnometer (W_1).
- Fill it with distilled water at a known temperature, weigh again (W_2).
- Empty, clean, and refill the pycnometer with the food sample. Weigh again (W_3).

- Calculate Specific Gravity as follows:

$$\text{Specific Gravity} = \frac{W_3 - W_1}{W_2 - W_1}$$

2. Hydrometer Method (Floating Method): A hydrometer floats at different levels based on the density of the liquid. The liquid sample is poured into a tall cylinder. The hydrometer is placed in the liquid and allowed to float. The value at eye level where the liquid touches the hydrometer scale is read. Adjust for temperature if needed. The reading at the liquid surface gives the specific gravity. It is used in honey testing to check purity and also to determine sugar concentration in fruit juices and syrups.

3. Digital Density Meter: It measures density using an oscillating U-tube sensor and converts it into specific gravity. It is used in wine, beer, and soft drink industries for rapid analysis.

5.3.3 Viscosity

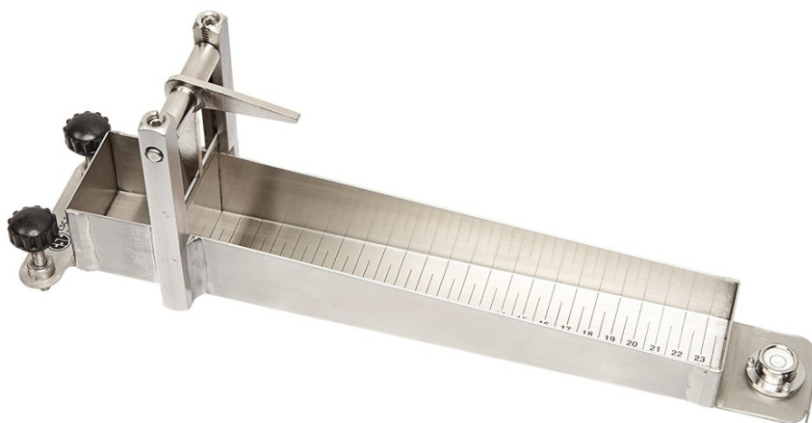
Viscosity analysis is an important aspect of food quality control, determining the thickness, flow behavior, and texture of liquid and semi-solid food products. It plays a key role in processing, packaging, and consumer acceptance, ensuring that products maintain consistent texture, stability, and mouthfeel. Viscosity is influenced by factors such as temperature, composition, and shear rate, making its measurement essential in industries like dairy, sauces, beverages, and confectionery.

Various methods are used for viscosity analysis, including rotational viscometers, capillary viscometers, and rheometers. Brookfield viscometers, one of the most common instruments, measure viscosity by rotating a spindle in the sample and recording the resistance encountered (Fig. 5.1 a). The Bostwick Consistometer evaluates the flow rate of semi-solid foods like ketchup and mayonnaise, while capillary viscometers are used for more fluid samples such as juices and syrups (Fig. 5.1 b). Rheometers provide advanced viscosity measurements by assessing how a sample deforms under different forces, making them suitable for complex food systems like emulsions and gels. Viscosity directly affects product performance and consumer perception. In dairy products, for instance, yogurt and cream require optimal thickness for desirable texture, while in beverages, maintaining proper viscosity ensures uniformity and stability. In sauces and dressings, controlled viscosity prevents phase separation and enhances pourability. Additionally, in industrial food processing, understanding viscosity helps optimize pumping, mixing, and filling operations, reducing production issues and ensuring batch consistency.

By conducting regular viscosity analysis, food manufacturers can enhance product quality, improve shelf life, and ensure compliance with industry standards. Proper viscosity control is essential for delivering products with the right texture, consistency, and stability, ultimately improving consumer satisfaction.



(a)



(b)

Fig. 5.1 (a): Brookfield Viscometer (b) Bostwick Consistometer

5.3.4 Particle Size

Particle size analysis is an essential aspect of food science that determines the size distribution of solid particles in a food product. It plays a critical role in texture, solubility, stability, and overall product quality. The particle size of ingredients affects the mouthfeel of food, the rate of dissolution in liquids, and the efficiency of food processing operations. Smaller particles generally enhance smoothness and uniformity, while larger particles can impact structural integrity and flow properties. This is particularly important in industries such as dairy, baking, confectionery, and beverages, where precise particle size control is required to achieve consistent quality.

There are several methods used to analyze particle size in food products, each suited to different types of materials. Sieve analysis is a common technique for measuring granular products like flour and sugar by passing the sample through a series of sieves with progressively smaller mesh sizes. Laser diffraction is widely used for fine powders such as cocoa and instant coffee, where a laser beam measures how particles scatter light to determine their size distribution. Microscopy techniques, including optical and electron microscopy, provide visual and quantitative measurements of particle size and shape. Dynamic light scattering is applied in liquid and colloidal systems, such as emulsions and dairy-based drinks, to assess the stability and uniformity of dispersed particles. Controlling particle size in food processing ensures uniform texture, enhances product stability, and improves consumer acceptance. In chocolate production, maintaining a fine particle size ensures smoothness, while in flour milling, controlling granularity affects dough formation and baking properties. Particle size also influences the mixing behavior of powdered ingredients, affecting the consistency of dry food blends and beverages. In addition to sensory attributes, it impacts the bioavailability of nutrients in fortified foods, as finer particles may enhance absorption and digestibility.

5.3.5 Water activity

Water activity is a key parameter in food science that measures the availability of free water in a food product, which influences microbial growth, chemical stability, and shelf life. Unlike moisture content, which represents the total water present in a product, water activity refers to the proportion of unbound water that can participate in biochemical reactions and support the growth of bacteria, yeasts, and molds. It is expressed on a scale from 0 to 1, where 1 represents pure water and values below 0.6 generally indicate conditions where microbial growth is inhibited.

Water activity is commonly measured using water activity meters, which determine the equilibrium relative humidity of a sample. The sample is placed in a sealed chamber where it reaches

equilibrium with the surrounding air, and sensors measure the humidity, which correlates to the water activity level. This analysis is widely used in food industries to ensure safety and stability, particularly in products such as dried fruits, baked goods, dairy products, and meats. Controlling water activity is essential in food preservation and quality control. Lowering water activity through drying, freezing, or adding solutes such as salt and sugar helps extend shelf life by reducing microbial growth and enzymatic reactions. For example, in dehydrated foods, maintaining a water activity level below 0.6 prevents spoilage, while in bakery products, optimizing water activity helps maintain texture and freshness. Proper water activity management also plays a role in preventing undesirable chemical reactions such as lipid oxidation and enzymatic browning, ensuring product consistency and longevity.

5.3.6 Texture Analysis

Texture analysis is a fundamental aspect of food quality assessment that evaluates the physical properties of a product related to its structure, consistency, and mechanical behavior. It plays a crucial role in determining the sensory experience of food, influencing consumer perception and acceptance. The texture of a food product is influenced by various factors such as ingredient composition, moisture content, processing conditions, and storage. Proper texture evaluation ensures that foods meet desired characteristics such as crispiness, chewiness, smoothness, or firmness, depending on the product type.

There are several methods used for texture analysis, with instrumental techniques providing objective and quantifiable measurements. Texture profile analysis (TPA) is widely used to simulate the chewing process, measuring attributes such as hardness, cohesiveness, adhesiveness, springiness, and resilience. A texture analyzer applies controlled force to a food sample and records its response to compression, tension, or shear (Fig. 5.2). Other techniques include penetrometry, which measures the firmness of soft foods like butter and cheese by assessing the depth of penetration of a probe, and rheology, which studies the flow and deformation of semi-solid and liquid foods such as yogurt, sauces, and gels. Shear tests determine the force required to cut through foods like meat, while tensile tests evaluate the stretchability of products like dough and cheese. Texture analysis is critical in various food industries to ensure consistency and quality. In bakery products, it helps assess crumb softness and crust crispiness, while in dairy, it ensures the smoothness of yogurt and firmness of cheese. Meat texture evaluation determines tenderness, which directly impacts consumer preference. The confectionery industry relies on texture testing to ensure proper chewiness of gummy candies and the snap of chocolate bars. In snack foods, crispiness and crunchiness are measured to maintain product appeal. Texture analysis also plays a role in food processing optimization, allowing

manufacturers to adjust formulations, processing conditions, and packaging techniques to maintain the desired texture over the product's shelf life.



Fig. 5.2: Texture analyzer

5.4 CHEMICAL ANALYSIS

Chemical analysis of food is a critical aspect of food science used to determine the composition, nutritional value, safety, and quality of food products. It involves identifying and quantifying various chemical components such as moisture, proteins, carbohydrates, fats, vitamins, minerals, additives, contaminants, and toxic substances. This type of analysis is essential for ensuring regulatory compliance, detecting food adulteration, assessing nutritional content, and improving food processing techniques. Chemical analysis can be broadly categorized into proximate analysis, nutritional analysis, contaminant detection, and food additive assessment. Proximate analysis includes the determination of moisture, ash, protein, fat, fiber, and carbohydrate content, providing fundamental information about the nutritional and energy value of food. In nutritional analysis, specific micronutrients such as vitamins and minerals are analyzed to ensure that food products meet dietary recommendations. Contaminant detection is another crucial aspect of chemical analysis, identifying pesticides, heavy metals, mycotoxins, and foodborne pathogens that can pose health risks. Chromatographic and spectroscopic techniques such as gas chromatography-mass spectrometry (GC-

MS) and liquid chromatography-mass spectrometry (LC-MS) are commonly used for detecting contaminants in food samples. Food additive analysis ensures that preservatives, colorants, flavor enhancers, and emulsifiers are within permissible limits. Spectrophotometry and titration methods are often used to quantify artificial sweeteners, antioxidants, and acidity regulators. Proximate analysis of food will be discussed in this section.

5.4.1 Moisture Analysis

Moisture analysis is an essential component of food quality control that determines the water content in food products. Moisture affects texture, shelf life, microbial stability, and overall product quality. Excessive moisture can lead to spoilage and microbial growth, while insufficient moisture can cause undesirable texture changes and loss of freshness. There are several techniques used to measure moisture content in food, each suited to different types of food matrices. Some of them are given below:

- **Oven Drying Method (Gravimetric Method):** It is one of the most commonly used techniques, based on weighing the sample before and after drying. It is used for grains, flour, dairy powders, and dehydrated foods. The method is simple and cost-effective, however it may not be suitable for foods containing volatile compounds. The food sample is heated at 105°C in an oven until a constant weight is achieved. The moisture content is calculated using the formula:

$$\text{Moisture Content (\%)} = (\text{Initial Weight} - \text{Final Weight} / \text{Initial Weight}) \times 100$$

- **Vacuum oven drying method:** It is a widely recognized and highly accurate technique for determining the moisture content of food. According to AOAC recommendations, food samples are typically heated at a temperature range of 98 to 102°C under a reduced pressure of 25-100 mm Hg for a duration of 2 to 6 hours. For heat-sensitive or sugary food products, such as jams and confectionery, lower temperatures between 60 and 70°C can be used to prevent decomposition and maintain product integrity.
- **Karl Fischer Titration:** It is a chemical method that determines water content by titrating the sample with Karl Fischer reagent, which reacts specifically with water. The Karl Fischer titrimetric method is based on the quantitative reaction of water with an anhydrous solution of sulfur dioxide and iodine, dissolved in a mixture of pyridine and an alcohol. The Karl Fischer reagent consists of iodine, pyridine, sulfur dioxide, and methanol. Moisture determination using this method can be performed through volumetric titration, where the endpoint is identified by a brown color change,

or by coulometric titration, where the endpoint is detected electrochemically using a potentiometer. The method is highly accurate for low-moisture foods such as oils, fats, and dried products.

- **Infrared Moisture Analyzer:** Infrared moisture analysis is a fast and efficient method for determining the moisture content of food products using infrared radiation to evaporate water from a sample. Unlike traditional methods such as oven drying or vacuum drying, infrared moisture analysis provides near-instant results, making it ideal for real-time monitoring in food production. The principle of infrared moisture analysis is based on infrared absorption and heat transfer. When infrared radiation is applied to a food sample, water molecules absorb the energy, leading to rapid evaporation. An infrared moisture analyzer consists of key components such as an infrared heating element, which provides controlled infrared radiation to ensure uniform heating, and a weighing balance, which measures the sample's initial and final weight to determine moisture loss. This method is widely used for various food products, including grains, dairy powders, meat, and bakery items, where precise moisture control is essential for maintaining product quality, shelf life, and texture.
- **Distillation Method:** The method is based on the co-distillation of water with an immiscible solvent such as toluene or xylene. The food sample is heated in the presence of the solvent, causing the water in the sample to evaporate and mix with the solvent vapors. Since water and the selected solvent have different boiling points, they condense separately and collect in a graduated receiving tube, where the volume of water can be directly measured. The distillation method is a widely used technique for determining the moisture content in food products, particularly those containing volatile compounds, fats, or sugars. It is commonly applied to products such as oils, butter, syrups, and jams, where traditional drying methods may lead to sample degradation or inaccurate results due to chemical reactions or evaporation of non-water components.
- **Microwave Moisture Analysis:** The microwave moisture analyzer is a rapid and efficient method for determining the moisture content in food products by utilizing microwave energy to evaporate water from the sample. Microwave moisture analyzers work on the principle of dielectric heating, where microwaves generate heat by exciting water molecules in the sample. As the water molecules absorb microwave energy, they rapidly evaporate, and the loss of weight is continuously measured. It is a non destructive method which offers precise results with minimal sample preparation.

5.4.2 Protein Estimation

The total protein content in food and food products can be quantified either directly or by estimating total nitrogen and converting it to crude protein using an appropriate conversion factor. Protein content is typically calculated from total nitrogen, which is determined using method such as the Kjeldahl method or the Dumas/Pregl-Dumas method. However, certain nitrogen-containing compounds, including amides (found abundantly in young plant shoots), ammonium salts, nitrates, lecithin, nucleic acids, and purines present in tea, coffee, cocoa, and meat extracts, can contribute to variability in protein estimation. Though these compounds introduce minor errors, the calculated protein value remains useful as it provides a reliable approximation of true protein content and serves as an indicator of other nitrogenous components in the food matrix.

In addition to nitrogen-based methods, protein content can also be measured directly using techniques such as formal titration, UV spectrophotometry, the Lowry method, dye-binding methods, infrared spectrophotometry, nuclear magnetic resonance (NMR) spectroscopy, turbidimetry, and refractometry. These alternative methods provide more precise protein measurements and are widely applied in food quality control, nutrition assessment, and regulatory compliance.

- **Formal Titration Method:** The formal titration method is used for the quantitative determination of amino acids and proteins in food and biological samples. It is based on the neutralization of amino groups in proteins using formaldehyde as a blocking agent. This method is particularly useful for analyzing proteins in dairy products, meat, and plant-based foods and is known for its simplicity and reliability. Proteins contain free amino groups ($-NH_2$) that can react with acids or bases. In the formal titration method, formaldehyde is added to the sample, which reacts with the free amino groups to form N-methylol derivatives, rendering them non-reactive. This prevents amino groups from interfering in the titration process. The remaining acidic or basic groups in the protein are then titrated with a standard sodium hydroxide (NaOH) or hydrochloric acid (HCl) solution, and the protein content is determined based on the amount of titrant used. The formal titration method is less accurate for complex food matrices containing interfering compounds and also not suitable for hydrolyzed proteins where free amino groups are already modified.
- **Lowry Method:** It is a widely used colorimetric technique for determining protein concentration in food, biological, and biochemical samples. It is based on the reaction of proteins with copper ions under alkaline conditions, followed by the reduction of the Folin-Ciocalteu reagent, which produces a measurable blue color. This method is highly sensitive and specific, making it suitable for food analysis, enzyme studies, and protein quantification in dairy, meat, and plant-based

products. The Lowry method consists of two main reactions i.e. Biuret reaction where proteins react with copper sulfate in an alkaline solution, forming a copper-protein complex and reduction of Folin-Ciocalteu reagent where the copper-protein complex further reacts with the Folin-Ciocalteu reagent, leading to the formation of a blue-colored complex. The intensity of this color is directly proportional to the protein concentration in the sample and is measured spectrophotometrically at 750 nm.

- **Kjeldahl Method:** The Kjeldahl method is a widely used chemical technique for determining total nitrogen content in food, which is then used to calculate protein content. It is commonly applied in the food, feed, and agricultural industries for quality control and regulatory compliance. This method is suitable for measuring protein in dairy products, meat, cereals, grains, and animal feed. The method is based on the assumption that protein contains approximately 16% nitrogen. The total nitrogen content is first determined, and the protein content is then calculated using a conversion factor, typically 6.25 for most food products. The Kjeldahl method consists of three main steps:
 1. **Digestion:** The food sample is digested in concentrated sulfuric acid (H_2SO_4) with a catalyst (such as selenium or copper sulfate). Organic nitrogen present in the sample is converted into ammonium sulfate $(\text{NH}_4)_2\text{SO}_4$. The digestion process breaks down proteins and removes carbon as CO_2 , leaving only nitrogenous compounds.
 2. **Neutralization and Distillation:** The digested mixture is neutralized by adding sodium hydroxide (NaOH), which releases ammonia (NH_3) gas. The ammonia is distilled into a boric acid solution, forming ammonium borate.
 3. **Titration:** The ammonia content is determined by titrating the boric acid solution with standardized sulfuric acid (H_2SO_4) or hydrochloric acid (HCl). The nitrogen content is calculated based on the amount of acid used, and the protein content is determined using the appropriate conversion factor.

$$\text{Protein Content} = \text{Total Nitrogen} \times \text{Conversion factor}$$

5.4.3 Fat Analysis

Oils and fats from oilseeds, fruits, and animal tissues are effectively extracted using diethyl ether, along with sterols and phosphorus-containing compounds like lecithins. Various solvents, such as chloroform, carbon tetrachloride, and petroleum distillates, can also dissolve fats and oils, though extraction yield and composition vary by solvent. Free fats are extracted using less polar solvents like petroleum ether, while bound fats require more polar solvents such as alcohols. Hydrolysis or chemical

treatment can release bound fats, meaning the extracted fat content depends on the analysis method used.

- **The direct solvent extraction method:** It is a widely used technique for determining fat content in food by directly dissolving fats and oils using organic solvents. In this method, a finely ground food sample is mixed with a suitable solvent, such as petroleum ether, hexane, or diethyl ether, which selectively dissolves lipids. The mixture is then filtered or centrifuged to separate the fat-containing solvent from the solid residue. The solvent is subsequently evaporated, leaving behind the extracted fat, which is then weighed to determine the fat content. This method is commonly used for foods with high fat content, such as oilseeds, nuts, dairy, and processed foods. It is a relatively quick and efficient technique but may not be suitable for samples containing bound fats, which require additional hydrolysis before extraction. The accuracy of the direct solvent extraction method depends on the choice of solvent, extraction conditions, and sample preparation.
- **The solubilization extraction method:** It is used to determine fat content in food by dissolving lipids in a suitable solvent system. Unlike direct solvent extraction, this method involves breaking down fat-protein or fat-carbohydrate complexes to release bound fats, making it particularly useful for foods where fat is not freely extractable, such as dairy products, meat, and emulsified foods. The process typically involves treating the sample with solubilizing agents, such as detergents, strong acids, or bases, to disrupt structural components and release fat into a solvent like ethanol, chloroform, or a mixture of solvents. The extracted fat is then separated, dried, and weighed to determine the fat content. This method provides a more complete fat extraction compared to direct solvent extraction, making it useful for analyzing total fat in complex food matrices. However, careful selection of solvents and solubilizing agents is required to prevent interference from non-fat components.

5.4.4 Fibre Content

Crude fiber analysis is a method used to determine the indigestible portion of plant-based foods, primarily composed of cellulose, hemicellulose, and lignin. It is an essential parameter in food and feed analysis, particularly for evaluating the fiber content in cereals, grains, fruits, vegetables, and animal feed. The analysis involves a sequential chemical digestion process where the sample is first treated with a dilute acid, such as sulfuric acid, to simulate gastric digestion, followed by treatment with a dilute alkali, such as sodium hydroxide, to mimic intestinal digestion. This process removes soluble components like proteins, sugars, and lipids, leaving behind the fibrous residue, which is then dried, weighed, and ashed to determine the crude fiber content. Although widely used, crude fiber

analysis does not account for all fiber components, such as pectin and some hemicelluloses, making more advanced methods like the Van Soest detergent method or enzymatic fiber analysis preferable for detailed fiber profiling.

Dietary fiber analysis is essential in food science and nutrition to determine the total fiber content in food products. Unlike crude fiber, which only accounts for insoluble cellulose and lignin, dietary fiber includes both soluble and insoluble fiber components, such as cellulose, hemicellulose, lignin, pectin, gums, and resistant starch. These fiber components play a crucial role in digestion, regulating blood sugar levels, lowering cholesterol, and promoting gut health. The analysis of dietary fiber is commonly performed using enzymatic-gravimetric methods, where food samples are digested with enzymes to remove starch and protein, followed by filtration, drying, and weighing to measure the fiber content. More advanced techniques, such as high-performance liquid chromatography (HPLC), are used to quantify specific fiber fractions, including soluble and insoluble dietary fiber. Dietary fiber analysis is particularly important in cereal products, fruits, vegetables, legumes, and processed foods formulated for digestive health benefits.

5.4.5 Ash Content

Ash is the inorganic residue left behind after the complete combustion of organic material. It serves as a measure of product quality and provides insight into the nutritional composition of food products. Ash content analysis is a method used in food testing to determine the total mineral content of a food sample. The process involves incinerating the sample at high temperatures, typically between 500°C and 600°C, until all organic matter is burned off, leaving behind inorganic residues such as calcium, magnesium, potassium, sodium, and trace minerals. The remaining ash is then weighed to calculate the percentage of ash content in the food. This analysis is commonly used in the quality control of cereals, dairy products, meat, fruits, vegetables, and animal feed to assess mineral composition and detect adulteration. Different methods for ash content determination include dry ashing, wet ashing, and low-temperature plasma ashing, each suited for specific food samples. Dry ashing is the most widely used method, where the sample is incinerated in a muffle furnace, while wet ashing uses strong acids to break down organic material for mineral analysis. Some of these acids are partially lost through volatilization, while the soluble minerals stay dissolved in nitric acid.

5.4.6 Reducing and Non Reducing Sugars

Sugars are classified into reducing and non-reducing sugars based on their ability to donate electrons and reduce oxidizing agents, such as Fehling's or Benedict's solution. This property depends

on the presence of a free aldehyde (-CHO) or ketone (-C=O) group in the sugar molecule. Reducing sugars contain a free aldehyde or ketone group, allowing them to act as reducing agents by donating electrons to oxidizing agents. These sugars react with Fehling's, Benedict's, or Tollen's reagent, forming a red precipitate of cuprous oxide (Cu_2O) in Fehling's/Benedict's test. Non-reducing sugars do not have a free aldehyde or ketone group, as their reactive carbonyl group is involved in a glycosidic bond. As a result, they cannot reduce Fehling's or Benedict's reagent. These sugars must be hydrolyzed into their monosaccharide components before they exhibit reducing properties.

The Lane and Eynon volumetric method is used to determine the reducing and total sugar content in food samples by utilizing Fehling's solution. Reducing sugars and non-reducing sugars (after hydrolysis) reduce copper ions in Fehling's solution, forming a red precipitate of cuprous oxide. The sugar concentration is estimated by measuring the volume of the unknown sugar solution required to completely reduce a known volume of Fehling's solution. Fehling's solution consists of an alkaline copper sulfate solution ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, 6.9%) and Rochelle salt (sodium potassium tartrate, $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$, 34.6%), which acts as a complexing agent to maintain copper ions in solution. Methylene blue is used as an oxidation-reduction indicator to determine the endpoint of the reaction. The indicator is added to the reaction mixture, and its color change signifies the completion of sugar reduction. Methylene blue is decolorized by even small amounts of reducing sugars but retains its color as long as any cupric ions remain in solution. The reaction is carried out in a boiling solution to prevent reoxidation, ensuring accurate results. Unlike acid-base indicators, where the endpoint is marked by a shift in color along the spectrum, oxidation-reduction indicators such as methylene blue exhibit a change in color intensity, making them effective for sugar determination.

5.4.7 Starch Content

Starch is a complex carbohydrate made up of amylose and amylopectin and serves as a primary source of energy in many plant-based foods such as cereals, tubers, legumes, and processed foods.

- **The acid hydrolysis method:** The method is used to determine the starch content in food samples by breaking down starch molecules into simpler reducing sugars using dilute acids. In this process, the food sample is treated with a strong acid, such as hydrochloric acid, and heated under controlled conditions to hydrolyze the starch into glucose and other simple sugars. After hydrolysis, the resulting reducing sugars are quantified using methods such as Fehling's or Benedict's test, which involve the reduction of copper ions to form a colored precipitate. The intensity of the color formed is proportional to the concentration of reducing sugars, allowing for

the estimation of the original starch content. Although acid hydrolysis is a simple and effective method, it may cause degradation of some sugars, leading to slight underestimation of starch content. To improve accuracy, enzymatic hydrolysis methods are often preferred in modern food analysis.

- **The enzymatic hydrolysis method:** It is a widely used technique for determining starch content in food products by breaking down starch molecules into simpler sugars using specific enzymes. This method provides higher accuracy and selectivity compared to acid hydrolysis, as it avoids the degradation of sugars and ensures complete conversion of starch into glucose. The process typically involves two key enzymes: α -amylase, which breaks down starch into dextrins and maltose, and amyloglucosidase, which further hydrolyzes these intermediates into glucose. The resulting glucose concentration is then measured using colorimetric assays such as the glucose oxidase-peroxidase (GOD-POD) method or high-performance liquid chromatography (HPLC). Enzymatic hydrolysis is commonly used in food analysis for cereals, bakery products, dairy formulations, and brewing processes to accurately quantify starch levels. This method is preferred due to its specificity, efficiency, and minimal risk of sugar degradation, making it suitable for applications in food quality control, nutritional labeling, and industrial processing.

5.5 MICROBIOLOGICAL ANALYSIS

5.5.1 Pour Plate Method

The pour plate method is a widely used microbiological technique for quantifying microorganisms in a given sample. It is commonly applied in environmental, food, and clinical microbiology to enumerate bacteria, yeasts, and molds present in a sample. In this method, a small volume of the sample is first introduced into a sterile petri dish. Molten agar medium, maintained at a temperature of 45-50°C, is then poured into the dish to prevent thermal damage to microorganisms. The sample and agar are thoroughly mixed to ensure even distribution, after which the medium is allowed to solidify at room temperature. The petri dish is then incubated under optimal conditions for the microorganisms to grow.

After incubation, colonies of microorganisms appear within and on the surface of the solidified agar. These colonies are counted to determine the microbial load in the sample. The method is based on the principle that as the agar solidifies, microorganisms are evenly dispersed, leading to the formation of distinct colonies. A key advantage of the pour plate method is that it facilitates the isolation of individual colonies, allowing further identification and study of specific microorganisms. It

is particularly useful for detecting and quantifying microbes present in low concentrations. However, the technique can be time-consuming and requires precision to ensure proper sample distribution within the agar.

5.5.2 Membrane Filtration Method

The membrane filtration method is a widely used technique for quantifying microorganisms, particularly in samples with low bacterial concentrations. This method utilizes membrane filters with specific pore sizes designed to retain bacteria while allowing the passage of liquids. In this procedure, a known volume of the sample is passed through a sterile membrane filter. The filter is then transferred onto an agar plate or an absorbent pad saturated with a nutrient medium and incubated under appropriate conditions to support bacterial growth. After incubation, colonies that develop on the membrane are counted microscopically, providing an estimate of microbial concentration in the original sample.

To enhance the efficiency and accuracy of bacterial detection, the use of fluorescent dyes and epifluorescence microscopy has been widely adopted since the early 1970s, particularly for water sample analysis. Initially, cellulose filters were used, but polycarbonate nucleopore filters are now preferred as they trap all bacteria on the surface, improving detection precision and colony visualization. This method is particularly valuable in water quality testing, pharmaceutical microbiology, and environmental monitoring, where detecting even low microbial counts is critical.

5.5.3 Most Probable Number (MPN) Technique

The Most Probable Number (MPN) method is a statistical approach used to estimate the concentration of viable microorganisms in a sample by assessing their growth in liquid broth at ten-fold serial dilutions. It is widely applied in environmental, agricultural, and water microbiology to determine microbial populations in soil, water, and food products. MPN is particularly useful for water quality testing, helping assess bacterial contamination levels. One of its key applications is detecting fecal coliform bacteria, which serve as indicators of fecal contamination. In this method, the water sample undergoes serial dilution and is inoculated into lactose broth. If coliform bacteria are present, they ferment the lactose, producing acid and gas. Acid production causes a color change in the medium, while gas formation is observed as bubbles trapped in an inverted Durham tube within the broth. The total number of coliforms is determined by counting the positive tubes (those showing both

color change and gas production) at each dilution level. These results are then compared to MPN statistical tables to estimate the microbial concentration in the original sample.

5.5.4 Enzyme-Linked Immunosorbent Assay (ELISA)

The enzyme-linked immunosorbent assay (ELISA) is a widely utilized immunological and molecular biology technique for detecting and quantifying specific antigens or antibodies in a sample. This method relies on the binding interactions between antigens and antibodies, followed by enzymatic detection to measure the presence or concentration of the target molecule. The assay is commonly performed on solid surfaces, such as microplates, where the antigen or antibody is immobilized, and detection is achieved using enzyme-conjugated reagents that produce a measurable signal. ELISA offers high accuracy, specificity, and scalability, making it ideal for analyzing multiple samples in high-throughput screening. However, careful validation, optimization, and inclusion of proper controls are essential to ensure reliable and interpretable results.

5.5.5 Polymerase Chain Reaction (PCR)

Polymerase Chain Reaction (PCR) is a molecular biology technique used to amplify specific DNA sequences in vitro. Developed by Kary Mullis in the 1980s, PCR has transformed genetic research, medical diagnostics, forensics, and biotechnology. The PCR process involves cyclic temperature changes to facilitate DNA amplification. It consists of three main steps: denaturation (94–98°C) to separate DNA strands, annealing (50–65°C) where primers bind to the target sequence, and extension (72°C) where DNA polymerase synthesizes new DNA strands using dNTPs as building blocks. This cycle repeats, leading to an exponential increase in DNA copies. The amplified DNA can be analyzed through gel electrophoresis, DNA sequencing, or hybridization-based assays like TaqMan and SYBR Green for real-time detection. PCR has revolutionized genetic testing, infectious disease diagnosis, and forensic investigations, enabling researchers to study genetic material with high precision and sensitivity.

5.6 SENSORY ANALYSIS

Sensory evaluation is a scientific discipline used to assess food products based on human senses, including taste, smell, sight, touch, and hearing. It plays a crucial role in food quality assessment, product development, and consumer preference studies. Unlike instrumental analysis, which provides objective data on physical and chemical properties, sensory evaluation focuses on how

consumers perceive and experience food. It is widely used in the food industry to ensure consistency, optimize formulations, detect differences between samples, and predict consumer acceptance before market launch.

Sensory evaluation involves trained panelists or consumers who systematically assess food products using standardized methods. The process is conducted in a controlled environment to minimize external influences and ensure reliable results. Sensory attributes are classified into different categories, including appearance, aroma, taste, texture, and aftertaste. Appearance includes color, shape, and surface characteristics, which influence consumer expectations. Aroma is evaluated based on volatile compounds released from the food, which contribute to flavor perception. Taste involves primary sensations such as sweetness, sourness, bitterness, saltiness, and umami, while texture assesses mechanical properties like crispiness, chewiness, smoothness, and firmness. Aftertaste refers to lingering flavors and sensations experienced after swallowing. There are different types of sensory tests, each designed for specific objectives (Table 5.1). Discrimination tests (e.g., triangle test, duo-trio test, paired comparison test) determine whether there is a perceptible difference between samples. These are commonly used in quality control to assess ingredient substitutions or processing modifications. Descriptive analysis tests (e.g., quantitative descriptive analysis, flavor profile analysis, texture profile analysis) provide detailed sensory profiles by evaluating specific attributes in a structured manner. These tests are essential for new product development and sensory mapping. Affective tests (e.g., hedonic scale test, ranking test, consumer acceptance test) measure consumer preferences and liking based on subjective opinions, helping companies understand market potential and consumer preferences. Sensory evaluation is critical in various food sectors, including bakery, dairy, beverages, confectionery, and processed foods. It ensures that products meet consumer expectations, maintain quality standards, and remain competitive in the market.

Table 5.1: Types of Sensory Tests and Their Applications in Food

Sensory Test Type	Description	Applications in Food Industry
Discrimination (Difference) Tests	Determine whether there is a perceptible difference between two or more samples.	Used in quality control to detect formulation changes, ingredient substitutions, or process modifications.
Triangle Test	Panelists receive three samples, two of which are identical, and must identify	Used in reformulation to check if changes in ingredients affect

	the different one.	sensory perception.
Duo-Trio Test	A reference sample is given, followed by two test samples; panelists must identify which matches the reference.	Used in product development to compare new formulations with existing products.
Paired Comparison Test	Two samples are presented, and panelists choose the one with a specific characteristic (e.g., sweetness, crispiness).	Used to compare competitor products or evaluate ingredient modifications.
Descriptive Analysis Tests	Provide detailed sensory profiles by evaluating specific attributes such as flavor, texture, and appearance.	Used in new product development and sensory mapping for flavor and texture profiling.
Quantitative Descriptive Analysis (QDA)	Trained panelists rate intensity levels of different sensory attributes on a scale.	Used in bakery, dairy, and beverage industries to evaluate product texture, aroma, and taste.
Flavor Profile Analysis	Identifies dominant and secondary flavor components in a product.	Used in beverage and spice industries to maintain consistent flavor profiles.
Texture Profile Analysis (TPA)	Assesses multiple texture characteristics such as hardness, chewiness, and cohesiveness.	Used in dairy, bakery, and confectionery products to optimize mouthfeel.
Affective (Hedonic) Tests	Measure consumer preferences and liking based on personal opinion rather than analytical evaluation.	Used in consumer research to assess overall product acceptability.
Hedonic Scale Test	Consumers rate their liking of a product on a scale (e.g., 1 to 9, where 1 = dislike extremely, 9 = like extremely).	Used in snack, beverage, and confectionery industries to test new product formulations.
Ranking Test	Panelists rank multiple samples based on preference or intensity of a specific	Used to determine the most preferred variant among multiple

	attribute.	prototypes.
Consumer Acceptance Test	Measures overall acceptability and willingness to purchase.	Used in market research before launching a new product.

5.7 SUM UP

After completing this unit, learners will understand the significance of food analysis in ensuring quality, safety, and regulatory compliance. They will gain knowledge of various methods used for food analysis, including physical, chemical, microbiological, and sensory evaluation techniques. In physical analysis, learners will explore the measurement of colour, specific gravity, viscosity, particle size, water activity, and texture, along with their impact on food quality and consumer perception. Chemical analysis will cover essential methods for determining moisture, protein, fat, fibre, ash content, reducing and non-reducing sugars, and starch content, emphasizing their role in food composition and stability. Learners will also gain insights into microbiological analysis, including techniques such as the pour plate method, membrane filtration, the most probable number (MPN) technique, enzyme-linked immunosorbent assay (ELISA), and polymerase chain reaction (PCR), which are crucial for detecting microbial contamination and ensuring food safety. Finally, they will understand the principles of sensory analysis and its importance in evaluating food attributes such as taste, texture, and aroma. This knowledge will equip learners with the necessary skills to assess food quality, optimize processing techniques, and ensure compliance with industry standards.

5.8 CHECK YOUR PROGRESS

1. Explain:

a) Viscosity

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b) Specific Gravity

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c) Most Probable Number

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d) ELISA

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2. Explain the methods used for estimation of protein content.

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3. Explain different types of discrimination test used in sensory evaluation.

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4. Differentiate between reducing and non reducing sugars. Explain the Lane and Eynon method.

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5. Explain the methods for measurement of specific gravity.

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6. Explain any two methods for analysis of moisture content.

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7. Write a short note on particle size analysis.

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UNIT-VI FOOD LAWS AND REGULATIONS

Structure

- 6.1 Introduction
- 6.2 National Food Legislation
- 6.3 Prevention of Food Adulteration Act
- 6.4 Essential Commodities Act
- 6.5 Bureau of Indian Standards (BIS)
- 6.6 AGMARK
- 6.7 Consumer Protection Act
- 6.8 Food Safety and Standards Authority Of India (FSSAI)
- 6.9 USFDA
- 6.10 Sum Up
- 6.11 Check your Progress

6.1 INTRODUCTION

National food standards play a vital role in ensuring the quality, safety, and reliability of products and services across various industries. In India, several regulatory bodies establish and enforce these standards to protect consumer interests, prevent unfair trade practices, and promote industrial growth. Organizations such as the Bureau of Indian Standards (BIS), AGMARK, and the Food Safety and Standards Authority of India (FSSAI) set scientific benchmarks for manufacturing, labeling, packaging, and distribution of goods, ensuring that they meet both domestic and international requirements. These regulatory frameworks help in maintaining food safety, ensuring accurate weights and measures, and providing certification for agricultural and industrial products. The implementation of national standards fosters consumer trust, enhances product quality, and supports fair trade practices. This unit explores the structure, functions, and significance of national food standards in India, highlighting how they contribute to public health, safety, and economic development.

Objectives

After learning this unit, you will be able to:

- understand the importance of national food legislation
- recognize the compulsory legislation and voluntary standards
- explain the PFA act
- identify the key regulatory bodies such as BIS, AGMARK, and FSSAI
- explain the significance of certification marks for agricultural goods
- analyze the role of FSSAI in ensuring food safety, regulating food production
- recognize the impact of standardization on trade, exports, and consumer protection
- explain the importance and role of USFDA

6.2 NATIONAL FOOD LEGISLATION

National Food Legislation refers to a set of laws, regulations, and standards established by a country to ensure the safety, quality, and labeling of food products. These laws govern food production, processing, distribution, and sale, aiming to protect public health and consumer rights. National food legislation often aligns with international guidelines, such as those set by the Codex Alimentarius, while considering local dietary habits, agricultural practices, and public health concerns. Key aspects include food safety regulations, hygiene requirements, permissible additives, contamination limits, and labeling standards. Regulatory bodies enforce compliance through inspections, testing, and penalties for violations. India's food laws are governed by a comprehensive framework to ensure food safety, quality, and consumer protection. The Food Safety and Standards Authority of India (FSSAI), established under the Food Safety and Standards Act, 2006 (FSS Act, 2006), is presently the primary regulatory body overseeing food standards, hygiene, and labeling.

However, earlier various food laws were enforced by different Ministries and Departments, primarily serving two key purposes:

1. Regulating Food Specifications – Ensuring food meets defined safety and quality standards.
2. Regulating Hygienic Conditions in Processing and Manufacturing – Establishing hygiene protocols during food production.

These laws and standards can be broadly categorized into two systems:

A. Compulsory Legislations

These laws are legally binding and must be followed to ensure food safety and quality.

1. Prevention of Food Adulteration Act, 1954
2. Essential Commodities Act, 1954, under which the following orders are issued:
 - Fruit Products Order (FPO), 1955
 - Sugar Control Order, 1966
 - Meat Products Order, 1973
 - Cold Storage Order, 1980
 - Milk Products Order
 - Vegetable Oil Products Order, 1976

B. Voluntary Standards

These standards serve as guidelines to improve food quality and safety but are not legally mandatory.

1. Bureau of Indian Standards (BIS)
2. Directorate of Marketing and Inspection (DMI)
3. Eco-Mark (Certification for environmentally friendly products)
4. ISO Standards (International quality and safety benchmarks)
5. HACCP (Hazard Analysis and Critical Control Points – food safety management system)

Some of the important legislation will be discussed further in this unit.

6.3 PREVENTION OF FOOD ADULTERATION ACT

The Prevention of Food Adulteration Act, 1954 (PFA) was enacted by the Government of India to regulate food quality, prevent adulteration, and ensure consumer safety. This law aimed to curb the sale of contaminated, substandard, or misbranded food products by establishing strict guidelines on food composition, permissible additives, labeling, and hygiene standards. The Act defined various forms of food adulteration and prescribed penalties for violations, including fines and imprisonment. It empowered food inspectors to conduct inspections, collect samples, and take legal action against offenders. The PFA, 1954, was a crucial step in maintaining food safety until it was repealed and replaced by the Food Safety and Standards Act (FSSA), 2006, which consolidated multiple food regulations under a single framework.

Details regarding permitted coloring agents, preservatives, and other additives are specified in various sections of the PFA Rules, 1955, as amended (Table 6.1). The relevant sections are as follows:

- **Part VI** – Coloring Matter
- **Part X** – Preservatives
- **Part XI** – Poisonous Metals
- **Part XII** – Antioxidants, Emulsifying, Stabilizing, and Anti-Caking Agents
- **Part XIII** – Flavoring Agents and Related Substances
- **Part XVI** – Sequestering and Buffering Agents

Table 6.1: Prevention of Food Adulteration Act, 1954 (PFA) regarding food additives:

Category	Regulations under PFA, 1954	Purpose
Permitted Colors	Only synthetic colors permitted under specified limits (e.g., Sunset Yellow, Tartrazine, Ponceau 4R).	Prevents harmful artificial color usage.
Preservatives	Permitted chemical preservatives include benzoic acid, sulfur dioxide, and sorbic acid within defined limits.	Inhibits microbial growth and extends shelf life.
Artificial Sweeteners	Permitted sweeteners include saccharin, aspartame, and cyclamates (within limits).	Controls sugar substitutes in food products.
Emulsifiers & Stabilizers	Substances like lecithin, glycerides, and gums are allowed for maintaining texture and consistency.	Prevents ingredient separation in food.
Antioxidants	Approved antioxidants like BHA (Butylated hydroxyanisole) and BHT (Butylated hydroxytoluene).	Prevents rancidity in fats and oils.
Prohibited Substances	Additives like non-permitted colors, certain artificial sweeteners, and unapproved preservatives are banned.	Ensures consumer safety and prevents toxicity.
Labeling Requirements	Food products containing additives must clearly mention their name, category, and INS number.	Ensures transparency and consumer awareness.

The labeling requirements for packaged foods in India are governed by Part VII of the PFA Rules, 1955, and the Standards of Weights and Measures (Packaged Commodities) Rules, 1977, as amended. These regulations mandate that food labels provide essential details to ensure transparency and consumer safety.

Mandatory Information on Labels:

1. **Product Name/Trade Name/Description** – Clearly mention the name of the food item.
2. **List of Ingredients** – Display ingredients in descending order of weight or volume.
3. **Manufacturer/Packer/Importer Details** – Provide the complete name and address, including the country of origin for imported products.
4. **Net Quantity** – Specify the weight, volume, or number of units contained.
5. **Batch/Lot/Code Number** – Include a unique identifier for traceability.
6. **Manufacturing & Packing Date** – Indicate the month and year of production.
7. **Best Before Date** – Mention the month and year by which the product should be consumed.
8. **Maximum Retail Price (MRP)** – Clearly state the retail price of the product.

Additional Labeling Requirements (Where Applicable):

- **Irradiated Food** – Must indicate the purpose of irradiation and display the license number.
- **Coloring Matter** – Declare if any artificial colors have been added.
- **Non-Vegetarian Products** – Must feature a brown-filled circle inside a square with a brown outline, displayed prominently near the product name. This applies to foods containing animal-derived ingredients (excluding milk and milk products).
- **Vegetarian Products** – Must display a green-filled circle inside a square with a green outline, positioned near the product name.

Labels must be printed in English or Hindi (Devanagari script). Importers are responsible for ensuring proper labeling before customs clearance, and products with only standard U.S. labels are not permitted for sale in India. Additionally, Section 32A mandates that any food product enriched with nutrients (such as minerals, proteins, or vitamins) must specify the exact quantities of added nutrients on the label.

6.4 ESSENTIAL COMMODITIES ACT

The Essential Commodities Act, 1955 (ECA) is a law enacted by the Government of India to regulate the production, supply, and distribution of essential commodities to ensure their availability at fair

prices and prevent hoarding, black marketing, and profiteering. The Act empowers the government to control the pricing, storage, and movement of essential goods, including food items, medicines, fertilizers, petroleum products, and other necessities. It also allows the government to impose stock limits and regulate trade during shortages or inflationary periods. Over time, amendments have been made to align the Act with changing market conditions, including the Essential Commodities (Amendment) Act, 2020, which sought to deregulate certain food items to promote private investment while retaining government intervention during extraordinary circumstances. Under this Act, several Control Orders have been issued over the years to oversee specific commodities. Below is a detailed explanation of the key Control Orders:

Fruit Products Order (FPO), 1955: The Fruit Products Order (FPO), 1955, was introduced to regulate the manufacture, quality, and distribution of processed fruit and vegetable products in India. It covers fruit-based products like fruit juices, jams, squashes, pickles, chutneys, and canned fruits. It aimed to ensure that consumers get safe, hygienic, and high-quality fruit products. It requires manufacturers to obtain an FPO license before producing or selling fruit-based products. Products that meet the quality criteria receive the FPO mark, indicating compliance with food safety standards. The order has been replaced by the FSSAI regulations in 2011 under the Food Safety and Standards Act, 2006.

Sugar Control Order, 1966: The Sugar Control Order, 1966, was introduced to regulate the price, production, and distribution of sugar to ensure its availability at fair prices. The government had the authority to fix sugar prices to prevent hoarding and black marketing. Direct sugar mills to sell a certain percentage of their sugar to the government at a controlled rate. In 2013, the government removed levy sugar obligations (which required sugar mills to sell a portion of their sugar to the government at a fixed price for Public Distribution System (PDS)).

Meat Products Order, 1973: This order was introduced to ensure the quality and hygiene of meat and meat products in India. It regulates the production, processing, and marketing of meat products. It ensures hygienic slaughtering, storage, and packaging of meat. It also mandates licensing and inspection of meat processing units. The order has also been replaced by the FSSAI regulations in 2011 under the Food Safety and Standards Act, 2006.

Milk and Milk Products Order (MMPO): This order regulates the production, distribution, and quality of milk and dairy products to ensure fair prices for farmers and safe products for consumers. All milk producers handling more than 10,000 liters per day must obtain a license. It ensures hygienic

processing and packaging of milk and dairy products. The Milk and Milk Products Order (MMPO) was replaced by the FSSAI regulations in 2011 under the Food Safety and Standards Act, 2006.

Vegetable Oil Products Order, 1976: This order was introduced to regulate the production, storage, and distribution of vegetable oil and its products. It ensures the quality and safety of edible oils and vegetable fats. It also mandates fortification of edible oils with Vitamin A and D as well as prevents the adulteration of edible oils with non-edible substances. The regulation of vegetable oils now falls under the Food Safety and Standards Act, 2006, monitored by FSSAI.

6.5 BUREAU OF INDIAN STANDARDS (BIS)

The Indian Standards Institution (ISI) was established in 1945 as a registered society under a Government of India resolution. It played a crucial role in setting national standards to support industrial and commercial growth, quality production, food microbiology, and competitive efficiency. However, recognizing the need for a stronger National Standards Body in response to a rapidly changing socio-economic landscape, the government granted ISI statutory status through the Bureau of Indian Standards (BIS) Act, 1986. On April 1, 1987, the newly formed BIS took over the staff, assets, liabilities, and functions of the former ISI. This transition aimed to foster a culture of quality awareness and encourage greater consumer participation in the formulation and implementation of national standards.

The primary objectives of BIS include the harmonious development of standardization, marking, and quality certification, providing a renewed focus on standardization and quality control, and integrating national standards with the growth and development of production and exports. The product certification scheme is primarily voluntary, designed to ensure quality, safety, and reliability for consumers. Products bearing the Standard Mark indicate compliance with prescribed specifications, which is maintained through regular surveillance, including surprise inspections and sample testing from both factories and markets. While the scheme itself is voluntary, the Government of India has made certification mandatory for 135 products in the interest of public health, safety, and mass consumption. These mandatory certifications are enforced through government orders issued under various Acts, while BIS continues to grant licenses based on applications from manufacturers. Under the provisions of the PFA Act, it is mandatory that commonly used food additives permitted for specific food items such as condensed milk, various types of milk powder, infant milk substitutes, infant food, and mineral water, are sold only with the ISI Certification Mark.

6.6 AGMARK

AGMARK is a certification mark issued by the Government of India to ensure the quality and purity of agricultural products. It is regulated by the Directorate of Marketing and Inspection (DMI) under the Agricultural Produce (Grading and Marking) Act, 1937. AGMARK covers over 200 commodities, including cereals, pulses, edible oils, spices, honey, milk products, and essential oils. The certification process involves inspection, sample testing, and quality verification in AGMARK-certified laboratories. While AGMARK is voluntary for most products, it is mandatory for certain items like edible oils and pulses. Unlike FSSAI, which ensures food safety and hygiene, AGMARK focuses on purity and quality grading of agricultural goods. The certification helps consumers trust the authenticity of products while enabling farmers to fetch better prices for graded produce. With the introduction of online certification, the government has made the process more accessible, ensuring higher quality standards for both domestic and export markets. The Directorate of Marketing and Inspection operates 21 laboratories and 50 sub-offices across the country. The Central Agmark Laboratory in Nagpur is responsible for research and development in this field.

6.7 CONSUMER PROTECTION ACT

To safeguard consumers from exploitation and protect them from adulterated, substandard goods and deficient services, the Consumer Protection Act was enacted. It came into effect on April 15, 1986, and applies across India, except for the state of Jammu and Kashmir. Under this Act, a statutory Consumer Protection Council has been established by the Ministry of Civil Supplies and Consumer Affairs to address consumer grievances related to product quality, including food items. The Act also mandates the formation of similar councils at state and district levels to enhance consumer protection measures. The Consumer Protection Act (COPRA) of 1986 was replaced by the Consumer Protection Act of 2019. The 2019 Act was passed to address shortcomings of the 1986 Act, and to strengthen consumer protection in the digital era. This Act establishes consumer rights, product liability, penalties for misleading advertisements, and a three-tier dispute resolution system to ensure fair treatment for consumers. Online platforms like Amazon, Flipkart, and other digital marketplaces are also covered under the Act. E-commerce companies must provide full product details, including price, warranty, and return policy. It also ensures fair refund policies for consumers and avoids unfair trade practices and misleading advertisements.

The Act recognizes six fundamental consumer rights:

1. **Right to Safety** – Protection from hazardous goods and services.
2. **Right to Information** – Access to accurate product details (price, ingredients, quality, etc.).
3. **Right to Choose** – Freedom to select from a variety of products and services.
4. **Right to be Heard** – Consumer complaints must be acknowledged and addressed.
5. **Right to Seek Redressal** – Compensation for unfair trade practices or defective goods/services.
6. **Right to Consumer Education** – Awareness about rights and responsibilities.

6.8 FOOD SAFETY AND STANDARDS AUTHORITY OF INDIA (FSSAI)

The Food Safety and Standards Authority of India (FSSAI) is the regulatory body responsible for ensuring food safety and quality in India. Established under the Food Safety and Standards Act, 2006, FSSAI consolidates various food laws to create a single, science-based regulatory framework. It sets standards for food products, regulates their manufacture, storage, distribution, sale, and import, and ensures that food is safe for consumption. FSSAI operates under the Ministry of Health and Family Welfare and is responsible for granting food licenses, conducting inspections, and monitoring food safety compliance. The authority also promotes consumer awareness and implements regulations to prevent food adulteration and contamination, ensuring the availability of safe and wholesome food in the country. FSSAI is responsible for framing food standards, licensing food businesses, and enforcing regulations. The Act ensures that food is manufactured, processed, stored, and distributed safely. The Act mandates that all food businesses (FBOs), including manufacturers, retailers, restaurants, importers, and storage units, must register with FSSAI and obtain a license based on their size and turnover.

Salient Features:

- The Food Safety and Standards Act introduces a single regulatory authority to establish food standards and oversee the manufacturing, import, processing, distribution, and sale of food products.
- It integrates key provisions of the Prevention of Food Adulteration (PFA) Act and aligns with international food safety regulations, including those set by the Codex Alimentarius Commission. The Act consists of 12 chapters with 101 clauses and two schedules.
- The Food Safety and Standards Authority of India (FSSAI) comprises representatives from various ministries, state governments, the food industry, consumer organizations, and farmers' associations.

It is supported by scientific committees and panels that assist in setting food standards, while a Central Advisory Committee helps in prioritizing regulatory activities.

- The authority operates from its headquarters in Delhi, with provisions for establishing offices across India. Enforcement of food safety regulations is carried out through state-level authorities, including the State Commissioner for Food Safety and local municipal bodies.
- The Food Authority is chaired by an appointed official and consists of 22 members, one-third of whom must be women. The Central Government appoints the Chairperson and other non-ex officio members based on recommendations from a selection committee. Additionally, a Chief Executive Officer, holding a rank no lower than Additional Secretary to the Government of India, serves as the Member-Secretary of the Authority.
- The regulatory framework covers various aspects of food safety, including permissible limits on food additives, crop contaminants, pesticide residues, heavy metals, processing aids, mycotoxins, antibiotics, and pharmacologically active substances.
- It also establishes accreditation guidelines for food safety management certification bodies. Standards for food labeling are defined, covering health, nutrition, and special dietary claims while ensuring that information is not misleading. Nutraceuticals and dietary supplements are also brought under regulation, with strict labeling requirements.
- The Act imposes restrictions on food advertising, prohibiting misleading claims that contradict its provisions. Import regulations ensure that no unsafe, misbranded, or substandard food is brought into the country without proper licensing. Strict penalties have been proposed for violations, including fines of up to five lakh rupees for selling substandard food and up to three lakh rupees for misbranded food. Advertisements that falsely describe food products or mislead consumers may result in a penalty of up to ten lakh rupees, with provisions for consumer compensation in cases of injury or death due to unsafe food.
- A Food Safety Appellate Tribunal is proposed to handle disputes and appeals related to food safety regulations. While the food industry acknowledges the need for scientific oversight to protect consumers, concerns have been raised about the challenges of implementation, particularly due to the limited number of advanced laboratories for food testing. However, industry representatives view the Act as a positive step toward strengthening food safety regulations.
- The Central Advisory Committee, established by the Food Authority through notification, includes representatives from the food industry, agriculture, consumer organizations, research institutions, and food laboratories. Commissioners of Food Safety and the Chairperson of the Scientific Committee serve as ex officio members. Additionally, representatives from key ministries such as

Agriculture, Food Processing, Health, Biotechnology, Animal Husbandry, Consumer Affairs, Commerce, Environment, Panchayati Raj, Small-Scale Industries, and Public Distribution, along with government-recognized farmers' organizations, are invited to participate in discussions and deliberations.

6.9 UNITED STATES FOOD AND DRUG ADMINISTRATION (USFDA)

The United States Food and Drug Administration (USFDA) is a federal agency under the Department of Health and Human Services responsible for ensuring public health and safety. It regulates food, drugs, biologics, cosmetics, medical devices, and tobacco products to ensure they meet safety and efficacy standards. Established in 1906 under the Pure Food and Drug Act, the agency enforces food safety regulations, monitors drug development, and ensures proper labeling of consumer products. It oversees the approval process for new pharmaceuticals and medical devices, requiring rigorous scientific and clinical testing before market release. The USFDA also regulates dietary supplements, cosmetics, and radiation-emitting devices to prevent potential health risks. In addition to domestic regulations, the agency collaborates with international bodies to uphold global food and drug safety standards. It conducts inspections, issues recalls for unsafe products, and responds to public health emergencies. Through its comprehensive regulatory framework, the USFDA plays a crucial role in maintaining high health and safety standards in the United States and influencing international policies on food and drug regulation. The USFDA also provides consumer education programs to raise awareness about food and drug safety, labeling, and nutrition. Through its comprehensive regulatory framework, the agency not only safeguards public health in the United States but also influences international policies on food and drug regulation, setting benchmarks for safety and quality worldwide.

6.10 SUM UP

Upon completing this unit on food standards, learners will gain a comprehensive understanding of the regulatory frameworks governing food safety, quality standards, and consumer protection in India and internationally. They will be able to identify the key roles and responsibilities of organizations such as the Bureau of Indian Standards (BIS), AGMARK, FSSAI, and the USFDA in ensuring food and product safety. Learners will understand how the Essential Commodities Act, the Prevention of Food Adulteration Act (PFA), and the Food Safety and Standards Act (FSSA) contribute to maintaining quality standards and preventing adulteration in India. They will also grasp the importance of

AGMARK certification for agricultural products, BIS for industrial and consumer goods, and FSSAI for overall food safety regulation. Additionally, they will recognize how these regulatory bodies establish scientific standards, regulate labeling, and enforce penalties to protect consumers. By exploring the USFDA, learners will gain insight into how food and drug regulations function in the United States. Overall, this chapter will equip learners with the knowledge to assess food safety standards, interpret regulatory policies, and appreciate the significance of national and international quality assurance mechanisms in protecting public health and ensuring consumer trust.

6.11 CHECK YOUR PROGRESS

1. Explain the importance of national food legislation.

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2. List the various laws and standards established to ensure food safety.

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3. Explain the salient features of PFA Act.

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4. Write short notes on Milk and Milk Products Order and Fruit Products Order.

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5. Explain the salient features of Consumer Protection Act.

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6. Explain the importance of FSSAI. Also explain the functioning of FSSAI

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7. Write a short note on USFDA.

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मुक्त विश्वविद्यालय, प्रयागराज

MFN 117

FOOD SAFETY AND QUALITY CONTROL

BLOCK-3 CONCEPT OF FOOD SAFETY, FOOD CONTAMINANTS AND FOOD LABELLING

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BLOCK III: CONCEPT OF FOOD SAFETY, FOOD CONTAMINANTS AND FOOD LABELLING

Food safety is an essential aspect of public health, ensuring that the food we consume is safe, nutritious, and free from harmful contaminants. Block III is constituted of three units dealing with significant issues related to food safety. The block provides a comprehensive understanding of key concepts related to food safety, natural food contamination and food adulteration.

Unit VII gives an introductory concept to food safety. It encompasses the practices and conditions necessary to ensure that the food we consume is safe, nutritious, and free from harmful contaminants. The unit focuses on achieving food safety through coordinated effort across all stages of the food supply chain. It also delves into the factors influencing food safety, highlighting various concerns that impact societal well-being. Additionally, the unit examines the importance of food shelf life, exploring the factors that affect it and the methods used to evaluate and extend it, ensuring food remains safe and of high quality for consumption.

Unit VIII focuses on the various naturally occurring toxic substances in food that can pose potential risks to human health. It explores a diverse range of contaminants, including alkaloids, cyanogenic glycosides, lectins, toxic amino acids, and histamines, which are naturally produced by plants and animals as defense mechanisms against pests and pathogens. The unit examines the health implications of these compounds. Additionally, it addresses antinutritional factors present in plant-based foods that can interfere with nutrient absorption and overall dietary quality. Through this unit, learners will gain insights into the nature of these naturally occurring toxins, their effects on human health, and the strategies required to mitigate their impact, thereby ensuring food safety and public health.

Unit IX provides an overview of key areas of concern in food safety. It explores the various types of adulterants commonly found in food, methods for detecting them, and their potential long-term effects on human health. The unit also delves into emerging issues such as genetically modified foods and nanoparticles, highlighting their implications for public health and safety. Additionally, it emphasizes the importance of food inspection and safety measures in maintaining quality and compliance within the food industry.

UNIT-VII INTRODUCTION TO FOOD SAFETY

Structure

7.2 Introduction

7.3 Concept of Food Safety

7.4 Food Safety Issues

7.5 Factors affecting Food Safety

7.6 Importance of Safe Foods

7.7 Shelf Life of Food Products

7.8 Factors affecting Shelf Life

7.8.2 Intrinsic Factors

7.8.3 Extrinsic Factors

7.8.4 Biological Factors

7.8.5 Chemical Factors

7.8.6 Processing and Handling Factors

7.8.7 Storage and Transportation Conditions

7.9 Evaluation of Shelf Life

7.10 Sum Up

7.11 Check your Progress

7.1 INTRODUCTION

Food safety refers to the practices and conditions that ensure the food we consume is safe, healthy, and free from contaminants. It plays a crucial role in protecting public health by preventing foodborne illnesses, which can arise from consuming contaminated or improperly handled food. Ensuring food safety involves a combination of measures at every stage of the food supply chain, from production and processing to storage, transportation, and preparation. This unit of this course gives you an

introduction to fundamentals of food safety. Through this unit, we will try to examine the existing food safety issues. Factors affecting food safety covered in the unit will expose the reader to the various concerns for public health. We will also get an idea of significance of shelf life of food. Further, we will also understand the factors affecting shelf life and the methods for its evaluation.

Objectives

After learning this unit, you will be able to:

- comprehend the concept of food safety
- explain the factors affecting food safety
- discuss the significance of safe food
- understand the fundamental of shelf life
- explain the shelf life evaluation methods

7.2 CONCEPT OF FOOD SAFETY

Food plays a vital role in influencing our health, nutritional well-being, and overall productivity. Therefore, it is crucial to ensure that the food we consume is both safe and of high quality. Consuming unsafe food can result in numerous foodborne illnesses, a major global public health concern. Instances of health issues caused by contaminated or adulterated food are frequently reported in the media. Foodborne diseases not only pose risks of mortality but can also harm trade, tourism, and employment, causing economic setbacks. As a result, food safety and quality have become matters of global significance. Ensuring food safety and maintaining its quality are essential, whether at the household level or in large-scale production, processing, and preparation, to safeguard public health and prevent health crises. With advancements in technology, increased purchasing power, and growing consumer demand, a variety of processed and functional foods are now being produced. However, assessing the safety of these foods is imperative. The quality of both raw and processed food remains a critical public health issue that requires attention. In recent years, food safety challenges, both globally and in India, have evolved significantly. Issues related to food quality and safety have gained immense importance, underscoring the need for stringent measures to address these concerns.

Food safety is a critical scientific discipline focused on the proper handling, preparation, and storage of food to prevent foodborne illnesses. It involves adhering to specific practices to mitigate severe health risks and often intersects with food defense measures to safeguard consumers from harm.

In the food industry, food safety encompasses various aspects, including the origins of food, food labeling, hygiene, additives, pesticide residues, biotechnology policies, import/export inspection guidelines, and certification systems. At the market-to-consumer level, the focus shifts to ensuring that food considered safe in the market is handled and prepared properly before consumption. Food can act as a carrier of diseases between individuals and can also support the growth of harmful bacteria that cause food poisoning. While developed nations typically enforce stringent standards for food preparation, less developed countries face significant challenges, such as limited access to safe water a critical factor for ensuring food safety.

Food safety can be defined as an assurance that the food will not cause harm to the consumer when it is prepared and consumed according to its intended use. It refers to the practices, procedures, and measures implemented to ensure that food is free from harmful contaminants and safe for consumption. It encompasses all aspects of the food supply chain, including production, processing, storage, transportation, preparation, and serving, to prevent biological, chemical, physical, or radiological hazards that can lead to foodborne illnesses or injuries. Food safety aims to protect public health by maintaining the integrity and quality of food while complying with established regulatory standards and guidelines. The goal of food safety is to protect people from getting sick and to ensure the food they eat is healthy and of good quality.

7.3 FOOD SAFETY ISSUES

The food and culinary industry faces numerous challenges related to food safety, ranging from inadequate sanitation and unclear labeling to untrained staff and unsafe storage practices. Key food safety concerns include:

- **Foodborne Illnesses:** These result from contamination by bacteria, parasites, viruses, or harmful chemicals in food. Globally, foodborne illnesses are a major issue, with the WHO reporting approximately 600 million cases and 420,000 deaths annually. Many of these illnesses can lead to severe health complications or even fatalities.
- **Contamination (Biological, Chemical, or Physical):** A significant contributor to foodborne illnesses, contamination occurs when food is compromised by harmful microorganisms (biological), pesticide residues or improper chemical concentrations (chemical), or foreign objects (physical). Each type poses a serious threat to public health.

- **Improper Handling and Storage:** Failing to handle or store food properly is a widespread issue in the industry. Factors such as poor temperature control, cross-contamination, and unsanitary practices can lead to spoilage, bacterial growth, and the risk of foodborne illnesses.
- **Cross-Contamination:** This occurs when harmful microorganisms transfer from one surface or food item to another, often through reused machinery, tools, or equipment. Cross-contamination not only increases the risk of foodborne illnesses but also complicates allergen management protocols.
- **Allergen Management:** Managing allergens is a critical food safety concern. Even trace amounts of allergens, when handled improperly, can cause severe allergic reactions. Challenges like unclear labeling, insufficient staff training, or relaxed kitchen procedures exacerbate this issue, potentially jeopardizing public trust and public health.

Although they may seem separate, many food safety issues are closely connected and collectively threaten the safety and integrity of the food supply. The food industry faces several challenges in ensuring the safety of the products it manages. Some of the most significant industrial challenges are:

- **Supply Chain Complexities:** The modern food supply chain involves a vast network of stakeholders across production, processing, and distribution. Maintaining consistent safety and quality standards across all participants is a daunting task. This complexity makes it difficult to trace the origins of food products or identify the source of contamination when safety issues arise.
- **Globalization:** With food production and consumption crossing international borders, the food industry must navigate varying safety and quality standards in different regions. Ensuring consistency across diverse markets is challenging, especially with increased production and distribution. Globalization further complicates the enforcement of universal food safety standards.
- **Consumer Perceptions:** Consumer expectations around food safety and quality differ widely and are constantly changing. In a global market, varying perceptions of what constitutes safe and high-quality food create additional challenges. Limited access to clear information also makes it harder for consumers to make informed decisions, adding pressure on the food industry to meet diverse expectations.

7.4 FACTORS AFFECTING FOOD SAFETY

The quality of both raw and processed food is a significant public health concern that demands immediate attention. Over the past decade, food safety challenges, both globally and in India, have

evolved dramatically, elevating the importance of addressing issues related to food quality and safety. Several factors contribute to this growing concern:

- **Changing Lifestyles and Eating Habits:** With shifts in lifestyle, more people are consuming food prepared outside their homes. In commercial settings, bulk preparation, handling by multiple individuals, and preparation hours in advance increase the risk of contamination and spoilage if food is not stored properly.
- **Processed and Packaged Foods:** The growing availability of processed and packaged foods in the market makes ensuring their safety crucial.
- **Pre-Packaged Spices and Condiments:** Unlike earlier times when spices and condiments were processed at home, today's demand for pre-packaged individual spices and spice mixes, especially in urban areas, raises concerns about their purity and safety. Ensuring the quality of both raw and processed foods remains a pressing public health issue.
- **Complex Food Logistics:** The transportation and distribution of bulk food involve long gaps between processing and consumption. Managing risks and maintaining safety during mass production and distribution are critical.
- **Microbial Threats:** The rise in microbial adaptations, antibiotic resistance, and increased international travel has heightened the incidence of foodborne microbial diseases. Over the past 25–30 years, nearly half of all known foodborne pathogens have been discovered, yet many illnesses of unknown origins persist. Addressing these challenges requires the identification of emerging pathogens and the establishment of active surveillance networks at national and international levels.
- **New and Evolving pathogens:** Pathogens, as living organisms, continuously evolve. With improved methods for tracing outbreaks, scientists are finding that bacteria can survive in environments previously deemed safe. Fifty years ago, scientists had identified only four foodborne pathogens. Today, the list has grown significantly. In fact, three of the four pathogens now considered most critical by the Centers for Disease Control and Prevention (CDC) were not even recognized twenty years ago. These include *Campylobacter jejuni*, *Listeria monocytogenes*, and *Escherichia coli*.
- **Global Trade and WTO Agreements:** As a signatory of the World Trade Organization's non-tariff agreements, India has embraced global market opportunities, enabling countries to engage in international trade. In this context, it is essential to ensure the safety and quality of foods, both domestically and for imports. Efficient food standards and control systems are vital for safeguarding domestic food production, facilitating international trade, and ensuring consumer

health. All food manufacturers must comply with established quality and safety standards, with regular product testing to meet regulatory requirements.

The evolving nature of these challenges underscores the need for robust food safety measures, comprehensive risk assessments, and vigilant enforcement of food quality standards to protect public health and promote sustainable development. Given these factors, the demand for safe, wholesome, and nutritious food has grown significantly in the ever-evolving food industry. This heightened concern has not only expanded the scope of the sector but has also created a wide array of career opportunities in food safety, quality assurance, nutrition, and related fields.

7.5 IMPORTANCE OF SAFE FOODS

The integrity of food safety is a critical concern throughout the entire food supply chain. The food safety lifecycle begins with agricultural practices and continues through the packaging of finished products and their delivery to consumers. Ensuring food safety requires an understanding of potential threats that may compromise its stability. Food safety encompasses practices that ensure food remains safe and wholesome. Every participant in the food supply chain must adhere to established food safety standards to safeguard public health. These practices include measures like cooking food to the correct internal temperature using a thermometer, preventing cross-contamination through proper segregation, storing perishable items at appropriate cold temperatures, and implementing other critical control points to neutralize potential pathogens. Even consumers also play a vital role in maintaining food safety. They are expected to follow storage and preparation instructions, particularly for raw materials, and to demand safe, high-quality products. By reporting concerns about food safety issues, consumers contribute to a safer food system. The importance of safe foods is fundamental in maintaining public health and ensuring the well-being of individuals. Consuming safe food prevents foodborne illnesses caused by harmful bacteria, viruses, parasites, or chemical contaminants, which can lead to serious health complications, hospitalizations, and even fatalities. Safe food ensures proper nutrition by retaining essential nutrients and eliminating harmful substances that may affect the body's growth, immunity, and overall functionality. It is particularly vital for vulnerable groups such as children, pregnant women, the elderly, and individuals with weakened immune systems, who are at a higher risk of severe health outcomes from contaminated food. Beyond health, safe foods have significant economic and societal benefits. By reducing the incidence of illnesses, they minimize healthcare costs and productivity losses while fostering confidence in food systems. This trust extends to global food trade, where meeting strict food safety standard becomes crucial for international market access. Safe

food practices, encompassing proper production, handling, storage, and preparation, ensure the food supply chain remains free of contaminants. Moreover, consumer awareness and adherence to safe food handling practices are critical in sustaining food safety efforts, creating a culture that prioritizes health, hygiene, and accountability at every level.

7.6 SHELF LIFE OF FOOD PRODUCTS

From the moment food is manufactured, processed, or harvested, it begins to deteriorate. The rate at which this happens depends largely on the type of product. In retail stores, food products are typically displayed on shelves, counters, or stored in fridges and freezers. Many of these items travel considerable distances from their point of origin to reach their retail destination. If proper storage conditions are maintained throughout the supply chain, the products should remain in optimal condition for consumption or use until a specified date, ensuring no compromise to Safety; Quality; Taste; Texture and Effectiveness. Shelf lives can vary widely among different types of products, such as fresh, frozen, or canned goods. Some items are labeled with a “use-by” date, indicating safety, while others display a “best before” date, reflecting quality.

The shelf life of a food product refers to the length of time a food item remains safe to consume, retains its desired quality, and meets established nutritional, sensory, and safety standards when stored under recommended conditions. It is the period during which the product maintains its freshness, taste, texture, and appearance without significant deterioration or risk of harm to the consumer. The shelf life is influenced by factors such as the type of food, packaging, storage conditions (like temperature and humidity), and the presence of preservatives or processing methods used.

7.7 FACTORS AFFECTING SHELF LIFE

Several factors influence the shelf life of food products, determining how long they remain safe to eat and maintain their quality. These factors can be grouped into intrinsic i.e. properties of the food itself and extrinsic i.e. external conditions affecting the food as well as biological, chemical and processing factors. The details are given below:

7.7.1 Intrinsic Factors

- *Moisture Content*

High Moisture Foods like fresh fruits, vegetables, dairy, and meats are prone to microbial growth and spoilage due to their high water activity (aw). Low Moisture Foods such as dried foods like grains and powders have longer shelf lives because low water activity inhibits microbial growth.

- ***pH Level***

Foods with low pH (acidic foods, e.g., citrus fruits) naturally resist bacterial growth, extending shelf life. Neutral or slightly alkaline foods (e.g., meats, dairy) are more susceptible to spoilage due to their favorable environment for microorganisms.

- ***Nutrient Composition***

Foods rich in carbohydrates, proteins, or fats provide a conducive environment for microbial growth. For example, protein-rich foods like meats and seafood spoil faster due to their ability to support bacterial activity.

- ***Natural Enzymes***

Naturally occurring enzymes in food can cause spoilage by breaking down nutrients, leading to off-flavors, changes in texture, or discoloration. For example, enzymatic browning occurs in fruits like apples and bananas.

- ***Preservatives and Additives***

Foods containing natural or artificial preservatives (e.g., salt, sugar, vinegar, or chemical additives) have an extended shelf life by inhibiting microbial activity or oxidation.

7.7.2 Extrinsic Factors

- ***Temperature***

High Temperatures promote microbial growth, enzymatic activity, and chemical reactions, leading to faster spoilage whereas cold Storage slows down these processes, extending shelf life (e.g., refrigeration or freezing).

- ***Humidity***

High humidity can lead to moisture absorption in dry foods, causing caking, microbial growth, or spoilage. On the other hand low humidity may cause drying out or hardening of products like baked goods.

- ***Oxygen Exposure***

Oxygen promotes the growth of aerobic microorganisms and oxidation of food components, eg. Oxidation of fats leads to rancidity in products like oils and nuts. Modified atmosphere packaging (MAP) can reduce oxygen exposure and extend shelf life.

- ***Light Exposure***

Light can degrade nutrients, especially vitamins (e.g., vitamin C and riboflavin) and cause changes in color, flavor, or texture. Foods like milk, oils, and beverages are particularly sensitive to light.

- ***Packaging Materials***

Proper packaging (e.g., vacuum sealing, airtight containers) protects food from contamination, light, oxygen, and moisture. Poor-quality or damaged packaging can accelerate spoilage by allowing air, moisture, or pests to enter.

7.7.3 Biological Factors

- ***Microbial Contamination***

Growth of bacteria, yeasts, and molds is one of the primary causes of food spoilage. Contamination can occur during production, processing, or storage due to poor hygiene or handling practices.

- ***Pests and Infestations***

Rodents, insects, and other pests can damage food packaging and contaminate the product, reducing its shelf life.

7.7.4 Chemical Factors

- ***Oxidation***

Exposure to air causes oxidation, especially in fats and oils, leading to rancidity. Oxidation can also degrade the color and flavor of foods, such as in fruits and vegetables.

- ***Chemical Residues***

Residual pesticides, cleaning agents, or food additives can alter food quality or react with food components over time, impacting shelf life.

7.7.5 Processing and Handling Factors

- ***Processing Techniques***

Heat treatments like pasteurization, sterilization, or blanching kill harmful microorganisms and enzymes, extending shelf life. Techniques like freezing, drying, or vacuum packing also preserve food for longer periods.

- ***Hygiene and Handling***

Poor hygiene during production, packaging, or transportation can introduce contaminants that reduce shelf life.

7.7.6 Storage and Transportation Conditions

- ***Temperature Control***

Cold storage slows down microbial activity, while improper temperature management can cause rapid spoilage.

- ***Cross-Contamination***

Contamination from other food products, surfaces, or equipment can introduce microorganisms or allergens that shorten shelf life.

- ***Transportation and Distribution***

The conditions under which food is transported also play a critical role. Prolonged transportation can lead to spoilage if proper conditions aren't maintained. Cold chain breaks during transport can accelerate spoilage. Damage during transit can expose food to contaminants and environmental factors.

7.8 EVALUATION OF SHELF LIFE

Shelf life testing involves a combination of scientific and sensory methods to ensure food safety, quality, and consumer satisfaction. Depending on the product, a mix of microbiological, chemical, physical, and sensory tests is used, supported by advanced technologies and predictive models. These methods help manufacturers ensure the product meets regulatory standards and remains desirable throughout its lifespan. Determining the shelf life of food involves assessing how long a product remains safe and of acceptable quality under specified storage conditions. Various methods, ranging from laboratory testing to real-time observation, are used to evaluate shelf life. Below are some common methods:

1. Real-Time Shelf Life Testing

This method involves storing the food product under recommended conditions and monitoring its quality over time until it reaches an unacceptable state. Products are stored in actual retail or consumer storage conditions (e.g., refrigerators, freezers, or room temperature). Regular testing is performed to assess safety, sensory qualities (taste, smell, texture, appearance), and nutritional value. This method provides highly accurate results as it mimics real-world conditions however it is time-consuming, as it requires the full duration of the product's shelf life.

2. Accelerated Shelf Life Testing (ASLT)

ASLT predicts the shelf life by storing food under elevated stress conditions, such as higher temperatures, humidity, or light exposure, to accelerate deterioration. Here, the food is exposed to conditions harsher than normal to simulate the aging process and the changes in quality and safety are monitored over a shorter period. Commonly used for products with long shelf lives, such as canned goods, dried foods, and packaged snacks. This method provides quicker results compared to real-time testing though it may not fully reflect actual storage conditions.

3. Microbiological Testing

Microbial growth is a primary cause of food spoilage, making microbiological testing an essential method for determining shelf life. The samples are periodically tested for the presence and growth of bacteria, yeasts, and molds. Common tests include total plate counts and pathogen-specific tests (e.g., for *Salmonella* or *Listeria*). It can be employed for perishable items like dairy, meat, and ready-to-eat foods. This method ensures safety by identifying microbial contamination but it requires laboratory expertise and specialized equipment.

4. Chemical Analysis

Chemical changes, such as oxidation or enzymatic reactions, can impact shelf life. Testing these changes helps predict product stability against Lipid oxidation (rancidity in oils and fats); pH changes; Nutrient degradation (e.g., loss of vitamins); Moisture content and water activity. It can be commonly used for oils, beverages, and nutrient-sensitive products.

5. Sensory Evaluation

Human senses (taste, smell, texture, appearance) are used to determine when food no longer meets quality standards. For this method trained sensory panels or consumer studies are conducted at various

intervals and observations on flavor changes, texture loss, or off-odors are recorded. Sensory evaluation method captures consumer-relevant quality changes, is highly subjective and may vary between individuals.

6. Packaging Integrity Testing

Packaging plays a critical role in extending shelf life by protecting food from contamination and environmental factors. This process involves testing the effectiveness of packaging materials (e.g., vacuum seals, oxygen barriers) and assessing the impact of packaging on factors like moisture loss, oxygen exposure, and light penetration. It can be used for packaged foods such as frozen items, snacks, and beverages.

7. Physical Testing

This involves monitoring physical changes in the food product over time, such as texture, color, or structural integrity like measuring texture changes (e.g., crispiness of snacks or tenderness of meat); Color analysis using colorimeters or weight loss due to moisture evaporation. It is specifically useful for fresh produce, bakery items, and frozen foods.

8. Predictive Modeling

Predictive modeling uses mathematical and statistical tools to estimate shelf life based on historical data and product-specific parameters. Data on microbial growth rates, chemical reactions, or storage conditions is used to build a model, which predicts how long the product will remain safe and of acceptable quality. It is often used for new product development or when real-time testing isn't feasible, is cost-effective and time-efficient however it may require validation through physical testing.

7.9 SUM UP

This unit has updated you about the concept and issues regarding food safety. Through this unit, we understood the factors affecting food safety as well as about importance of safe foods. We also studied about shelf life of food products and the various factors affecting it. Further, the methods involved in evaluation of shelf life of food were also discussed.

7.10 CHECK YOUR PROGRESS

1. Define:

a) Food Safety

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b) Shelf life of Food

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c) Cross contamination

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2. Explain the importance of safe foods.

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3. Explain the intrinsic factors affecting shelf life of foods.

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4. Explain factors affecting shelf life of food.

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UNIT-VIII FOOD CONTAMINANTS OF NATURAL ORIGIN

Structure

- 8.1 Introduction
- 8.2 Food Contaminants
- 8.3 Plant Origin Contaminants
- 8.4 Animal Origin Contaminants
- 8.5 Antinutritional Factors
- 8.6 Sum Up
- 8.7 Check your Progress

8.1 INTRODUCTION

Unit VIII discusses the various naturally occurring toxic substances found in food that can pose risks to human health. It covers a wide range of contaminants, including alkaloids, cyanogenic glycosides, lectins, toxic amino acids, and histamines, which are produced by plants and animals as defense mechanisms against pests and pathogens. The unit examines how these compounds can lead to health issues when consumed in large quantities or under improper conditions. Additionally, the unit highlights antinutritional factors in plant-based foods that can hinder nutrient absorption. Overall, the unit will emphasize the importance of understanding the nature of these contaminants and the measures needed to reduce their impact on human health and food safety.

Objectives

After learning this unit, you will be able to:

- comprehend food contaminants
- describe the sources of naturally occurring contaminants
- explain the health effects of contaminants
- discuss the types of seafood poisoning
- explain the various antinutritional factors

- understand the importance of removal of toxins

8.2 FOOD CONTAMINANTS

Contaminants are unintended substances that can be found in food due to various stages of production, packaging, transportation, or storage. They may also arise from environmental pollution. As contaminants can adversely affect food quality and pose potential risks to human health, it is essential to implement measures to reduce their presence in food products. Food contaminants of natural origin are substances that occur naturally in food and can pose risks to human health if consumed in significant amounts. These contaminants can originate from plants, animals, or microorganisms.

Food contaminants are substances that are unintentionally introduced into food, potentially affecting its safety, quality, and suitability for consumption. These contaminants can originate from a variety of sources, including natural processes, environmental pollution, agricultural practices, or food processing and packaging methods. Contaminants can broadly be categorized into three types: biological, chemical, and physical. Physical contaminants are foreign objects unintentionally introduced during food handling, processing, or packaging. These include items like metal fragments, glass shards, plastic pieces, stones, and bone splinters. Such contaminants not only pose choking hazards but can also cause physical harm, such as cuts or dental damage. Biological contaminants include microorganisms such as bacteria, viruses, parasites, and fungi, which can cause foodborne illnesses. Common examples are *Salmonella*, *Escherichia coli* (E. coli), and *Listeria monocytogenes*, often found in raw or undercooked meat, poultry, eggs, and unpasteurized dairy products. Fungi can produce mycotoxins, such as aflatoxins, which contaminate crops like peanuts, maize, and grains. Additionally, biological contaminants include naturally occurring toxins like marine biotoxins from algae, which accumulate in seafood, or plant toxins such as lectins in raw legumes and cyanogenic glycosides in cassava and almonds.

Chemical contaminants can be naturally occurring or man-made. Naturally occurring chemicals include heavy metals like arsenic, lead, and mercury, which can accumulate in certain foods due to soil and water contamination. For instance, arsenic is often found in rice, while mercury accumulates in large predatory fish like tuna. Agricultural chemicals like pesticides, herbicides, and fertilizers used during farming can leave residues on food crops. Industrial chemicals such as environmental pollutants such as polychlorinated biphenyls (PCBs) and dioxins can enter the food chain through water, air, and

soil contamination. Food processing chemicals like additives, preservatives, or unintentional contamination from food contact materials, like plastic packaging or equipment, may introduce harmful chemicals such as bisphenol A (BPA) into food. The effects of food contaminants on human health range from mild discomfort to severe illness or even death. Biological contaminants can lead to foodborne illnesses with symptoms such as vomiting, diarrhea, and fever. Chemical contaminants, depending on the substance and level of exposure, may cause acute poisoning, developmental issues, or long-term effects like cancer and organ damage. Physical contaminants can cause immediate physical injuries or compromise the safety perception of food products.

As we have learnt, some contaminants in food occur naturally, while others originate from environmental pollution, and some are intentionally added to adulterate food; a topic we will explore in the next unit. In this unit, we will focus on natural contaminants present in foods (Fig. 8.1). To simplify their understanding, we have classified them as follows:

Naturally Occurring Toxicants:

- Toxic substances present in plants, such as alkaloids, cyanogenic glycosides, and lectins.
- Toxicants in animal-derived foods, such as marine biotoxins and histamines.
- Antinutritional Factors such as compounds like phytic acid and tannins, which can interfere with the absorption of nutrients in foods.

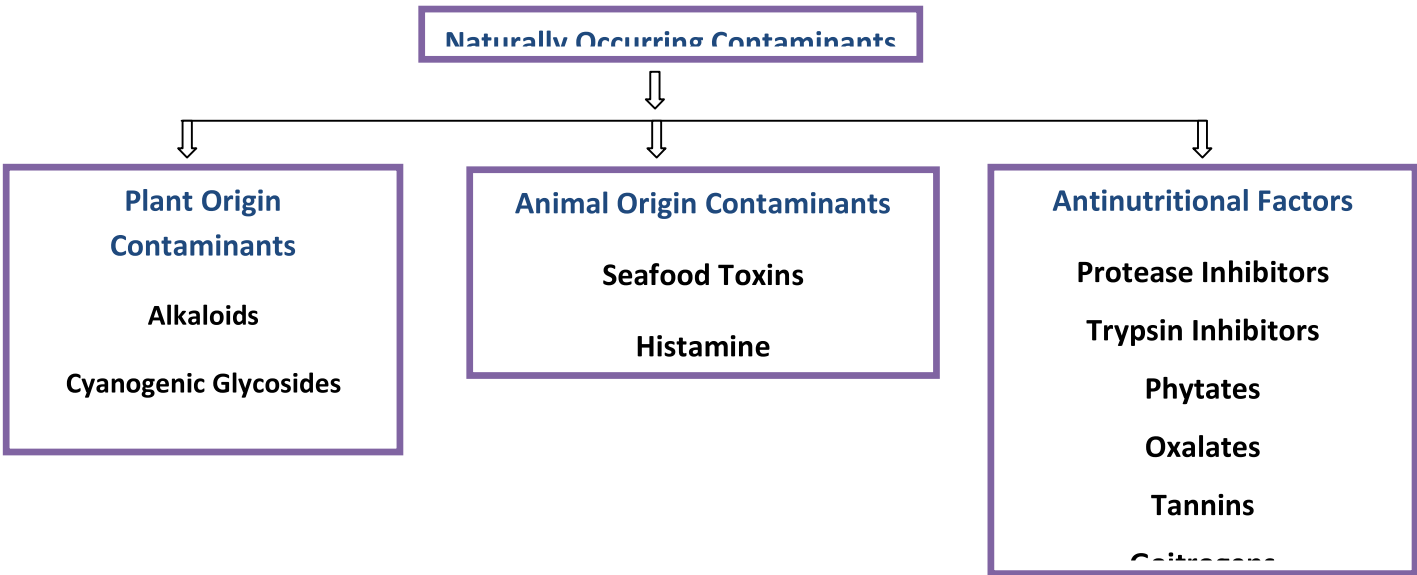


Fig. 8.1: Naturally occurring contaminants in food

8.3 PLANT-ORIGIN CONTAMINANTS

Plant-origin contaminants are naturally occurring substances in plants that can pose risks to human health if consumed in significant amounts. These substances can take the form of proteins, amino acids, alkaloids, or cyanogenic glycosides. These contaminants are often part of the plant's natural defense mechanisms against pests, herbivores, or environmental stress. Different types of natural toxins can be found in various crop plants, and these toxins may be present in different parts of the plant. The edible parts of crop plants include the foliage, buds, stems, roots, fruits, and tubers. Some common examples of natural toxins found in food plants are lectins in beans like green beans, red kidney beans, and white kidney beans; cyanogenic glycosides in bitter apricot seeds, bamboo shoots, cassava roots, and flaxseeds; glycoalkaloids in potatoes and muscarine in wild mushrooms. These toxins can pose health risks if not properly handled or prepared.

- **Alkaloids**

Alkaloids are naturally occurring organic compounds primarily found in plants, although some are also produced by fungi, bacteria, and animals. They are characterized by the presence of nitrogen atoms, often in a heterocyclic ring structure, and typically exhibit significant biological activity. The amine group in alkaloids gives them an alkaline nature when dissolved in water, which is the basis for their name "alkaloids." Alkaloids serve as a defense mechanism for plants, protecting them from herbivores and pests, but they can pose risks to human health when consumed in large quantities. Alkaloids have been extracted from the roots, seeds, leaves, or bark of plants belonging to at least 40% of all plant families. Some plant families that are especially rich in alkaloids include Amaryllidaceae, Compositae, Leguminosae, Liliaceae, Papaveraceae, and Solanaceae.

A commonly found alkaloid in the plant kingdom is pyrrolizidine alkaloid. These compounds are present in approximately 6,000 plant species across all climatic regions of the world. Ingestion of plants containing pyrrolizidine alkaloids typically occurs through contaminated crops. These alkaloid-containing plants often grow as weeds in food crops like wheat or corn, and may be harvested alongside the grain. Another potential source of exposure to these toxins is the consumption of herbal foods and preparations that contain pyrrolizidine alkaloids. In November-December 1975, an outbreak of veno-occlusive disease, likely caused by the consumption of cereals contaminated with seeds from a plant (*Crotalaria* sp.) containing pyrrolizidine alkaloids, occurred in the Sarguja district of India where out of the 67 recorded cases, 42% resulted in death.

In 1998, an outbreak of food poisoning due to epidemic dropsy, caused by mustard oil contaminated with Argemone oil, was reported in Delhi. The incident resulted in the loss of 60 lives, and over 3,000 individuals were hospitalized. Epidemic dropsy is a condition caused by the consumption of edible oils adulterated with *Argemone mexicana* oil. The two primary toxic alkaloids in Argemone oil, sanguinarine and dehydrosanguinarine, lead to widespread capillary dilation, proliferation, and increased permeability of blood vessels. The leakage of the protein-rich plasma component into the extracellular space results in the formation of edema. This accumulation of fluid causes swelling in the affected tissues.

Other plant alkaloids, such as glycoalkaloids, act as natural pesticides, helping protect plants from common pests. Examples of these alkaloids include solanine, found in small amounts in potatoes, and tomatine, which is present in tomatoes. These compounds serve as a defense mechanism for the plants but can be toxic if consumed in large quantities. Glycoalkaloids are composed of a steroidal alkaloid attached to one or more monosaccharide molecules. All plants in the Solanaceae family produce glycoalkaloid toxins. In potatoes, the primary glycoalkaloids are α -solanine and α -chaconine, which are formed in the parenchyma cells of the periderm and cortex of the tubers. These compounds are toxic to insects and animals, serving as a defense mechanism for the plant. While they are typically present in small amounts in all potato tubers, they are concentrated in the skin and in areas with high metabolic activity, such as the eyes. The concentration of glycoalkaloids increases in potatoes that have been exposed to light (greened) or are blighted, and can reach very high levels in the sprouts.

The primary concern with glycoalkaloid toxicity is its acute effects. Numerous cases of human poisoning, some fatal, have been reported due to the consumption of greened, damaged, or sprouted potatoes, which contain high levels of glycoalkaloids. Acute toxicity symptoms in humans have been observed when glycoalkaloid levels exceed 2.8 mg/kg of body weight. The onset of symptoms can occur anywhere from minutes to two days after ingesting toxic potatoes, with longer incubation periods generally linked to more severe cases. In mild poisoning, symptoms typically include gastrointestinal distress, such as diarrhea, vomiting, and intense abdominal pain. Solanum alkaloids have strong anticholinesterase activity on the central nervous system, and many alkaloids cause acute toxicity by either mimicking or blocking the action of neurotransmitters.

- **Cyanogenic Glycosides**

Cyanogenic glycosides are found in at least 2,000 plant species, many of which are used as food. These compounds are secondary metabolites derived from amino acids. Approximately 25 different

cyanogenic glycosides have been identified. Various types of cyanogenic glycosides can be found in different food plants that contain them, such as taxiphyllin in bamboo shoots and linamarin in cassava. Other edible plants containing cyanogenic glycosides include bamboo shoots, flaxseeds, seeds of stone fruits like apricot and peach, seeds of legumes such as lima beans, and the shells of soybeans (Fig. 8.2). Additionally, certain food products made from these plants may also contain cyanogenic glycosides. These include flavoring ingredients like ground almond powder or paste, marzipan, stone fruit preserves (e.g., cherry, plum, apricot, peach), stone fruit juices, and alcoholic beverages made from stone fruits. These foods can act as potential sources of hydrogen cyanide. The toxicity of plants containing cyanogenic glycosides arises from the cyanide released during ingestion.

In humans, acute cyanide intoxication can manifest through symptoms such as rapid breathing, a drop in blood pressure, an accelerated pulse, dizziness, headaches, stomach pain, vomiting, diarrhea, mental confusion, stupor, cyanosis, twitching, and convulsions, which may progress to terminal coma. Death from cyanide poisoning occurs when cyanide levels surpass the body's detoxification capacity. The acute lethal dose of hydrogen cyanide in humans is estimated to range between 0.5 and 3.5 mg per kilogram of body weight. Linamarin, a cyanogenic glycoside present in cassava, can be removed through water leaching. Cassava is typically consumed only after undergoing processes such as soaking, fermentation, and drying, which reduce the toxin levels in the root. Detoxification can also be achieved by chopping and grinding cassava under running water before cooking.



Bamboo shoots



Cassava



Lima Beans

Fig 8.2: Sources of Cyanogenic glycosides

- **Lectins**

Lectins, also known as phytohaemagglutinins, are proteins or glycoproteins of non-immune origin that possess multiple, highly specific carbohydrate-binding sites. Initially identified in castor beans,

lectins are now recognized as being widespread across the plant kingdom, including in grain products. They are especially concentrated in legume seeds and can cause gastroenteritis, nausea, and diarrhea in humans. Various types of beans, such as green beans, red kidney beans, and white kidney beans, are known to contain lectins.

Lectins are proteins that have the ability to bind to carbohydrates. The properties that enable lectins to protect plants in nature can pose challenges during human digestion. They are resistant to breakdown in the digestive system and remain stable in acidic environments. Raw or undercooked kidney beans are especially dangerous because they contain high levels of phytohaemagglutinin, a type of lectin that can cause red blood cells to clump together. Lectins can inhibit plasma membrane repair, which can make wounded cells toxic. They can also bind to the surface of gut epithelial cells and interfere with cellular metabolism. Studies on animals and cells have shown that active lectins can hinder the absorption of essential minerals, including calcium, iron, phosphorus, and zinc. Since legumes and cereals are rich sources of these minerals, the presence of lectins in these foods may reduce their bioavailability in the body. Additionally, lectins can bind to the cells lining the digestive tract, potentially disrupting nutrient breakdown and absorption. This interaction may also influence the growth and functioning of intestinal flora, further affecting digestive health.

Symptoms of acute lectin toxicity include severe stomach pain, vomiting, and diarrhea. Lectins can damage the gastrointestinal epithelium, disrupt cell division, cause local hemorrhages, and harm organs such as the kidneys, liver, and heart. They can also agglutinate red blood cells. Cooking with moist heat effectively reduces lectin toxicity, making lectin-containing plants safe for consumption after proper cooking. However, special care is needed when preparing these foods at high altitudes, where the boiling point is lower, when using low-heat cooking methods, or in situations where heat transfer may be uneven. To eliminate toxins, beans should be soaked and thoroughly boiled in fresh water. Cooking beans at low temperatures, such as in a crock pot, is not recommended, as it may fail to destroy the toxins effectively.

- **Toxic amino acids**

Toxic amino acids are naturally occurring amino acid analogs or derivatives found in certain plants and microorganisms that can have harmful effects on humans and animals. These toxins are found in several legume genera, such as *Lathyrus*, as well as in other plant families, seaweeds, and fungi. Some of these compounds hinder protein synthesis, while others integrate into proteins, causing harmful effects. Hypoglycin A, lathrogenic amino acids, mimosine, indospicine, and canavanine are examples

of toxic amino acids. While these compounds generally exhibit low acute toxicity, prolonged exposure or consumption can lead to adverse effects on various mammalian tissues.

Mimosine is generally found in *Leucaena leucocephala* (a leguminous plant), which interferes with cell division and protein synthesis, causing hair loss, growth retardation, and reproductive problems in animals. Canavanine is found in jack beans (*Canavalia ensiformis*). It mimics arginine, leading to faulty protein production and causing growth inhibition and metabolic dysfunction. BOAA (Beta-N-Oxalyl-L- α,β -Diaminopropionic Acid) is present in grass pea (*Lathyrus sativus*) and causes neurolathyrism, leading to spastic paralysis, particularly in the lower limbs. This compound acts as an excitotoxin, meaning it overstimulates and damages nerve cells, contributing to the onset of upper motor neuron disease. This condition has been particularly prevalent in regions of Madhya Pradesh, Chhattisgarh, Bihar, and Maharashtra in India, as well as in Bangladesh, where the implicated pulse has historically been consumed in large quantities. Another toxic amino acid is hypoglycin which is found in unripe ackee fruit (*Blighia sapida*) and certain other plants. It impairs fatty acid metabolism, leading to severe hypoglycemia and metabolic disorders like Jamaican vomiting sickness. Azetidine-2-Carboxylic Acid is found to be present in some plants like beets and lilies. It substitutes proline in proteins, causing structural defects and cellular toxicity.

Reducing the toxic effects of amino acids, especially those found in plants and foods, involves a combination of processing techniques, dietary practices, and awareness. Soaking seeds, legumes, or grains in water helps leach out water-soluble toxic compounds, including some toxic amino acids. High-temperature cooking can denature many toxic amino acids and reduce their toxicity. For example, prolonged boiling can lower the concentration of toxins like mimosine and hypoglycin A. Fermentation promotes the breakdown of toxic amino acids through enzymatic action and microbial activity. For example, fermented cassava products are safer due to reduced cyanogenic glycosides. Sun drying or roasting can also deactivate certain toxic amino acids by altering their structure.

8.4 ANIMAL-ORIGIN CONTAMINANTS

- **Seafood toxins**

Seafood toxins are naturally occurring compounds found in marine organisms, such as fish and shellfish that can cause foodborne illnesses in humans. These toxins are primarily produced by marine microorganisms, such as dinoflagellates and cyanobacteria, and can accumulate in seafood through the

food chain. Shellfish, including clams, oysters, scallops, and mussels, consume plankton and algae from the sea. While some types of plankton are harmless to the shellfish, they can be toxic to humans. Consuming shellfish that have ingested these toxic plankton can lead to poisoning.

Ciguatera poisoning is a type of food poisoning caused by consuming warm-water ocean fish contaminated with ciguatera toxin. This toxin is produced by dinoflagellates, tiny organisms that attach to algae in warm ocean reef areas. Herbivorous fish consume these toxic algae and are subsequently eaten by larger predatory fish, which may then be consumed by humans, passing the toxin up the food chain. Ciguatera poisoning symptoms typically begin within 1 to 24 hours after consuming contaminated fish and include a variety of discomforts. These can range from tingling or numbness in the fingers, toes, lips, and mouth, to a burning sensation when exposed to cold water. Affected individuals may experience joint and muscle pain, muscle weakness, nausea, vomiting, diarrhea, and abdominal cramps. Other symptoms include headache, fatigue, fainting, and severe itching that worsens with alcohol consumption. In the most severe cases, difficulty breathing may also occur.

Scombroid poisoning, on the other hand, results from consuming fish with elevated levels of histamine. This occurs when bacteria in the fish produce histamine due to improper handling, such as delayed chilling after capture or inadequate temperature control during storage. Histamine is produced in fish when bacteria on the fish convert an amino acid called histidine into histamine. Common fish associated with scombroid poisoning include mackerel, tuna, sardines, marlin, anchovies, and bonito. Scombroid fish poisoning typically occurs rapidly after consuming contaminated fish, often within 30 minutes, but it can also appear several hours later. Common symptoms include a peppery or metallic taste, flushing of the upper body, itching, headache, dizziness, and gastrointestinal issues such as vomiting, diarrhea, and abdominal cramps.

There are various other types of shellfish poisoning, each with distinct symptoms and severity. Paralytic shellfish poisoning is a serious and potentially fatal condition that affects the nervous system, with symptoms like numbness and tingling of the lips and extremities, along with gastrointestinal issues, usually appearing within half an hour to two hours of consuming contaminated shellfish. Amnesic shellfish poisoning is another severe illness that can lead to death or coma, affecting both the nervous system and the gut, with symptoms typically appearing within a day. Neurotoxic shellfish poisoning shares symptoms with ciguatera poisoning but is less severe, often lasting only a few days. Diarrhoeic shellfish poisoning results in diarrhea and vomiting, with symptoms appearing about half an hour after consumption but typically resolving within a few days.

The removal of shellfish toxins is challenging because these toxins are often not eliminated through normal cooking methods. Seafood toxins are heat-stable, meaning they are not destroyed by cooking or freezing. Therefore, the most effective way to avoid shellfish toxins is to harvest shellfish from areas known to be free from contamination. Shellfish should be kept on ice or refrigerated immediately after harvesting to slow down the accumulation of toxins. Quick cooling reduces bacterial growth and toxin production. In some cases, shellfish can be tested for toxins, particularly in regions known for shellfish toxicity.

8.5 ANTINUTRITIONAL FACTORS

Antinutritional factors are naturally occurring compounds in foods, particularly in plant-based foods, that interfere with the absorption or utilization of nutrients, or can cause harmful effects when consumed in excess. These compounds can reduce the nutritional value of food or contribute to health problems. Major anti-nutritional factors present in edible crops include tannins, saponins, phytic acid, lectins, gossypol, amylase inhibitors, protease inhibitors, and goitrogens. These anti-nutrients interact with nutrients and pose a significant challenge by decreasing the bioavailability of essential nutrients. Additional factors, such as trypsin inhibitors and phytates, which are primarily found in legumes and cereals, hinder protein digestibility and mineral absorption. Anti-nutrients play a crucial role in limiting the bioavailability of various nutrients in cereals and legumes, potentially leading to micronutrient malnutrition and mineral deficiencies.

- **Protease Inhibitors**

Protease inhibitors are naturally occurring compounds found in various plant foods, especially legumes, grains, and seeds. They work by inhibiting the action of proteases, which are enzymes that break down proteins during digestion. While protease inhibitors help protect plants from pests and pathogens, they can interfere with human digestion by reducing the availability of proteins for absorption. In humans, protease inhibitors can reduce protein digestibility since they block protease enzymes, which are crucial for breaking down proteins into smaller peptides and amino acids, they can decrease the efficiency of protein digestion. They can also affect nutrient absorption by impairing protein digestion, they may also affect the absorption of essential amino acids, leading to potential nutritional deficiencies if consumed in large amounts over time.

- **Trypsin Inhibitors**

Trypsin inhibitors, commonly present in various plant species, particularly in grain legumes, interfere with protein digestion by inhibiting the activity of the digestive enzymes trypsin and chymotrypsin in the gut. They represent a unique class of proteins that form indigestible complexes with dietary proteins. Trypsin inhibitors primarily interfere with the activity of trypsin, an enzyme secreted by the pancreas, in the gut. By inhibiting this enzyme, they disrupt the digestion of dietary proteins, forming complexes that reduce protein digestibility and impair the body's ability to effectively utilize these nutrients. These complexes remain resistant to digestion, even in the presence of high concentrations of digestive enzymes, significantly impairing protein bioavailability. Trypsin inhibitors are commonly found in a variety of plant and animal sources, particularly protein-rich foods. Among plants, legumes such as soybeans, lentils, chickpeas, peas, and kidney beans are notable for their high levels of trypsin inhibitors. Cereals like wheat, barley, rye, and oats, as well as nuts and seeds such as peanuts and sunflower seeds, also contain these inhibitors. Additionally, certain vegetables, including potatoes and sweet potatoes, contribute to dietary sources of trypsin inhibitors. In animal sources, raw egg whites contain protease inhibitors like ovomucoid and ovostatin. Raw soybeans contain high levels of trypsin inhibitors, which can lead to growth retardation and pancreatic hypertrophy. These inhibitors interfere with protein digestion and hinder the release of essential amino acids, such as methionine. Fortunately, trypsin inhibitors are generally heat-labile and are largely deactivated during regular cooking processes, making cooked soybeans and soybean products safer and more nutritious.

- **Phytates (Phytic Acid)**

Phytate, also referred to as inositol hexakisphosphate, is a phosphorus-containing compound that binds to minerals, thereby inhibiting their absorption. Phytates are commonly found in the seeds of vegetables, fruits, and grains, with unrefined cereals and millets being the richest sources. In contrast, refined or polished cereals, such as rice, contain lower levels of phytates. In cereals, phytates bind with minerals like iron, magnesium, zinc, and calcium to form insoluble complexes, which significantly reduce the absorption of these minerals. This can contribute to deficiencies, especially in populations relying heavily on cereal-based diets as their primary food source.

Phytate is primarily found in plant-based foods, particularly in seeds, grains, legumes, and nuts. Unrefined cereals such as wheat, barley, and oats, as well as millets like sorghum and pearl millet, are among the richest sources of phytate. Legumes, including soybeans, chickpeas, and lentils, also

contain significant amounts. Additionally, nuts such as almonds and walnuts, along with seeds like sunflower, pumpkin, and sesame seeds, contribute to dietary phytate intake. The levels of phytate are generally higher in unprocessed or whole foods and are lower in refined products, such as polished rice or white flour, due to the removal of the outer layers during processing.

- **Oxalates (Oxalic Acid)**

Oxalates, also known as oxalic acid, are naturally occurring compounds found in many plant foods. They can bind to minerals like calcium, iron, and magnesium, forming insoluble salts, such as calcium oxalate, which reduces the bioavailability of these minerals and can interfere with their absorption in the body. Present in foods like spinach, rhubarb, and beet greens, they can be a concern for individuals prone to kidney stones, as high levels of oxalates may contribute to the formation of calcium oxalate kidney stones. However, for most people, the amount of oxalates in foods is not harmful unless consumed in very large quantities. Consuming foods with excessive amounts of oxalic acid on a regular basis can lead to nutritional deficiencies, as oxalates bind to essential minerals like calcium, iron, and magnesium, reducing their absorption in the body. Additionally, high levels of oxalic acid can cause severe irritation to the lining of the gut, leading to digestive discomfort and potential long-term health issues.

- **Tannins**

Tannins are a group of naturally occurring polyphenolic compounds found in various plant foods, including fruits, vegetables, legumes, tea, coffee, and some grains. They are known for their astringent taste and are responsible for the bitter or puckering sensation in foods like unripe fruits and some teas. Tannins can have both beneficial and adverse effects on health. On the positive side, they have antioxidant properties, which can help protect cells from oxidative damage and may reduce the risk of chronic diseases like heart disease and cancer. Additionally, tannins have antimicrobial properties and may help protect against infections. However, tannins can also have negative effects, particularly on nutrient absorption. They can bind to proteins, iron, and other essential minerals, reducing their bioavailability and potentially leading to deficiencies, especially in people who rely heavily on plant-based diets. For example, tannins in tea and coffee can inhibit the absorption of non-heme iron (the type of iron found in plant foods), contributing to iron deficiency in some individuals. Tannins are heat-stable compounds that can decrease protein digestibility in both animals and humans. They likely reduce protein availability by either partially binding to proteins, making them less accessible for digestion, or by inhibiting digestive enzymes. This interference with digestion can lead

to an increase in fecal nitrogen, indicating poor protein utilization. As a result, high tannin levels in the diet can negatively impact protein absorption and overall nutrient availability.

- **Goitrogens**

Goitrogens are naturally occurring substances found in certain foods that can interfere with thyroid function by inhibiting the uptake of iodine, which is essential for thyroid hormone production. When consumed in large amounts, goitrogens can contribute to the development of a condition known as goiter, which is the enlargement of the thyroid gland due to iodine deficiency. There are two primary types of goitrogens i.e, glucosinolates which are found in cruciferous vegetables, such as broccoli, cabbage, kale, cauliflower, and Brussels sprouts. These compounds can inhibit iodine uptake by the thyroid gland and isoflavones found in soy products, such as tofu, soybeans, and soy milk. These compounds can affect thyroid function, especially in individuals with iodine deficiency. Although goitrogens can be harmful when consumed in excessive amounts, the risk is generally low for most people with adequate iodine intake. In fact, cooking can significantly reduce the goitrogenic activity of foods, as heat inactivates many of these compounds. Therefore, incorporating goitrogenic foods into a balanced diet that includes sufficient iodine usually does not pose a significant health risk.

- **Saponins**

Saponins are a class of naturally occurring compounds found in various plant foods, including legumes, grains, vegetables, and some herbs. Common sources include beans (such as soybeans, chickpeas, and lentils), peas, and other pulses. Saponins are also present in cereals like quinoa, oats, and barley. These compounds are typically concentrated in the outer layers of seeds and grains, which is why unprocessed or whole foods tend to have higher levels of saponins compared to refined products. They are glycosides, meaning they contain both a sugar and a non-sugar component. Saponins are known for their soap-like properties, as they can form foam when mixed with water due to their ability to disrupt cell membranes. Saponins can interfere with the absorption of essential nutrients like proteins, fats, and minerals by forming complexes with these nutrients or by disrupting the digestive process. High levels of saponins can also cause gastrointestinal irritation, leading to symptoms like nausea, vomiting, and diarrhea. They can also damage the lining of the gut, impairing nutrient absorption further. Similar to tannins, saponins can reduce protein digestibility by binding to proteins and forming complexes that are harder to break down during digestion. They can interfere with protein and mineral absorption and may have toxic effects if consumed in large quantities. They also have the potential to damage red blood cells.

The removal of anti-nutritional factors is crucial for improving the nutritional quality of food. Various traditional processing methods can be used to reduce the levels of these harmful compounds, such as saponins, tannins, phytic acid, protease inhibitors, and others. Techniques like fermentation, germination, debranning, autoclaving, and soaking are commonly employed to reduce the anti-nutrient content in foods. These processes work by either breaking down the anti-nutrients directly, leaching them into water, or modifying their structure to make them less effective. By applying one or a combination of these methods, it is possible to significantly decrease the levels of anti-nutritional factors, enhancing the bioavailability of essential nutrients and improving the overall nutritional value of food.

8.6 SUM UP

The unit on food contaminants of natural origin explored various naturally occurring substances in food that can be harmful to human health. These contaminants include toxic compounds found in plants and animals, which can pose risks when consumed. An understanding of various sources of toxins, symptoms observed and their effect on human body is given. Overall, the unit highlighted the complexity of natural food contaminants, their potential risks to human health, and the importance of understanding and managing them to ensure food safety.

8.7 CHECK YOUR PROGRESS

- 1. Define:
 - a) Food contaminants
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 - b) Antinutritional factors
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 - c) Saponins
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 - d) Goitrogens
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2. Match the following foods to the toxins they contain:

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|------------------------------|-----------------------|
| i) Cassava | a) Taxiphyllin |
| ii) Grass pea | b) BOAA |
| iii) <i>Lathyrus sativus</i> | c) Histamine |
| iv) Fish | d) cyanide precursors |
| v) Bamboo Shoots | e) Linamarin |

3. Explain the health effects of seafood toxins.

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4. Write a short note on oxalates and phytates.

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5. Explain the various contaminants of plant origin.

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6. List the methods for removal of toxins from natural sources.

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UNIT-IX CONCERNS IN FOOD SAFETY

Structure

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9.1 INTRODUCTION

Food safety is a critical aspect of public health, with growing concerns regarding the presence of adulterants, genetically modified organisms (GMOs), and nanoparticles in food products. This unit gives you an overview of areas of concern in food safety. Through this unit, we will try to examine the different adulterants used in food, their detection methods and their long term effects on human body. Topics like genetically modified foods and nanoparticles will expose the reader to the emerging concern areas for public health. We will also understand the significance of food inspection and safety measurement required in various food businesses.

Objectives

After learning this unit, you will be able to:

- explain the concept of food adulteration
- list various adulterants used
- discuss the evaluation methods of various adulterants
- understand the safety concerns of GMO's
- explain food inspection methods

- understand food safety measurement approaches

9.2 FOOD ADULTERATION

Food adulteration is a significant issue that impacts public health and safety. It involves the deliberate or accidental alteration of food products by adding, removing, or substituting substances to increase profits or meet consumer demands. Adulteration can occur in various forms, such as adding non-food-grade chemicals, mixing low-quality materials, or using harmful dyes to enhance the appearance and shelf life of food items. For example, water is commonly added to milk to increase its quantity, while harmful synthetic dyes are used to brighten sweets and vegetables. Fruits are often ripened artificially using chemicals like calcium carbide, which releases acetylene gas that poses severe health risks. Similarly, spices like chili powder and turmeric are adulterated with brick powder, lead chromate, or colored sawdust, while honey is diluted with glucose or sugar syrup to mimic natural sweetness.

In India, food contamination and adulteration typically occur either for financial gain or due to negligence and poor hygienic practices during processing, storage, transportation, and marketing. These practices often lead to consumers being cheated or, worse, becoming victims of various health issues. The lack of stringent quality control measures and inadequate awareness exacerbates the problem, making adulteration a prevalent issue. Such practices are particularly common in developing or economically backward countries, where limited resources and oversight further contribute to compromised food safety standards. The impact of food adulteration on health can be devastating. In the short term, it may cause food poisoning, nausea, vomiting, and diarrhea. However, prolonged consumption of adulterated food can lead to chronic diseases like cancer, kidney failure, liver damage, and compromised immunity. Certain adulterants, such as heavy metals like lead and arsenic, are especially dangerous and can accumulate in the body over time, causing irreversible damage and even death in severe cases.

Today, there is greater awareness than ever about the dangers of food adulteration, prompting updated regulations that emphasize the need for stronger protection at both governmental and industry levels. Consumers can use simple home tests to identify adulterated products, such as checking for chalk powder in sugar by dissolving it in water or identifying synthetic milk by heating it to observe residue. Additionally, buying food items certified by trusted agencies like FSSAI, ISI, or AGMARK helps ensure quality. Educational campaigns about food safety and the dangers of adulteration can

empower people to make informed choices and safeguard their health. Recognizing the critical role of food in society, modern communities view food adulteration as a heinous and unforgivable socio-economic crime. Notably, "Adulteration of foodstuffs and other food" is listed under the Concurrent List in the Constitution of India, highlighting its significance as a shared responsibility between the central and state governments. To combat this issue, the Indian Government introduced a key consumer protection law, the Prevention of Food Adulteration Act, 1954, aimed at curbing the practice and ensuring food safety for all citizens. The Food Safety and Standards Authority of India (FSSAI) enforces laws under the Food Safety and Standards Act, 2006, to ensure compliance with safety standards.

An article of food shall be considered adulterated under the following conditions:

- (a) If the food sold is not of the nature, substance, or quality demanded by the purchaser, or it fails to match what it claims or is represented to be, to the detriment of the purchaser.
- (b) If the food contains any other substance or has undergone processing that adversely affects its nature, substance, or quality.
- (c) If a cheaper or inferior substance has been wholly or partially substituted in the food, thereby negatively impacting its nature, substance, or quality.
- (d) If any component of the food has been wholly or partially removed, injuriously affecting its nature, substance, or quality.
- (e) If the food has been prepared, packed, or stored under unsanitary conditions, resulting in contamination or making it harmful to health.
- (f) If the food contains any filthy, putrid, rotten, decomposed, or diseased animal or vegetable matter, is insect-infested, or is otherwise unsuitable for human consumption.
- (g) If the food is derived from a diseased animal.
- (h) If the food contains any poisonous or harmful ingredient that renders it injurious to health.
- (i) If the container in which the food is stored is made, wholly or partially, of a poisonous or harmful substance that makes its contents unsafe.

- (j) If the food contains any unauthorized coloring agent or permitted coloring agents in amounts exceeding the prescribed limits.
- (k) If the food contains any prohibited preservative or an excessive amount of a permitted preservative beyond the allowable limits.
- (l) If the quality or purity of the food falls below the prescribed standards or its constituents are present in amounts beyond the permissible limits, rendering it harmful to health.
- (m) If the quality or purity of the food falls below the prescribed standards or its constituents exceed the allowable limits but do not render it harmful to health.

Exception: If the deviation in quality or purity of primary food occurs solely due to natural causes beyond human control, the food shall not be considered adulterated under this sub-clause.

9.3 ADULTERANTS

Adulterants are substances that are added to food items intentionally or unintentionally, compromising their quality, safety, and nutritional value. These substances are often used to increase the quantity or enhance the appearance of food products, primarily for financial gain, without considering the harmful effects on consumer health. Common adulterants include water added to milk, synthetic dyes in sweets, chalk powder in flour, and harmful chemicals like calcium carbide for ripening fruits. Unintentional adulteration can occur due to poor handling, contamination during storage, or the presence of pesticide residues in crops. Consumption of adulterated food can lead to a range of health issues, from mild food poisoning and allergies to severe conditions like cancer, kidney failure, and organ damage. Adulteration not only poses significant health risks but also erodes consumer trust in food products. Adulterants are typically chosen for their ability to enhance the apparent value of a product, serve as a cheaper substitute for more expensive ingredients, or conceal undesirable qualities. In some cases, adulterants are used to mask certain risks or contaminants. For instance, specific strains of naturally occurring *E. coli* are classified as adulterants under food safety laws, making it illegal to sell products containing these harmful organisms. This deliberate or unintentional use of adulterants highlights the need for stringent regulations to protect consumer health and maintain food integrity.

- **Adulteration in milk and milk products**

Adulteration in milk and milk products is a widespread concern that poses significant health risks to consumers. Milk, being a staple food, is often adulterated for economic gain, either by increasing its volume or enhancing its appearance. Common adulterants in milk include water, which dilutes its nutritional value, and substances like starch, detergent, and synthetic milk compounds, added to mimic the consistency and taste of pure milk. Dangerous chemicals such as urea, formalin, and caustic soda are sometimes used to preserve milk or enhance its thickness, despite their toxic effects on human health. Adulterated milk can lead to digestive problems, kidney issues, and long-term diseases. Milk products, such as butter, ghee, cheese, and curd, are also not immune to adulteration. Starch or vanaspati (hydrogenated fat) is often added to ghee and butter to increase weight, while synthetic colors and artificial flavoring agents are used in ice creams and flavored milk.

- **Adulteration in spices**

Adulteration in spices is a prevalent issue, especially in developing countries, where unscrupulous practices are used to increase profit margins at the expense of consumer health. Spices, being an essential part of daily cooking, are often adulterated with substances that mimic their appearance, texture, or weight. Common adulterants in spices include non-edible and harmful substances such as brick powder, salt powder, or red oxide in chili powder; lead chromate or colored chalk powder in turmeric; and powdered soapstone or yellow-colored starch in curry powder. In some cases, whole spices are adulterated with substances like lead polish, mineral oil, or harmful dyes to enhance their appearance. For example, black pepper is adulterated with dried papaya seeds, while clove stems are mixed with genuine cloves to increase weight. Ground spices are more susceptible to adulteration as their powdered form makes it easier to mix non-food substances. These adulterants not only reduce the quality of the spices but also pose severe health risks, including digestive disorders, kidney damage, and long-term toxicity due to the accumulation of harmful chemicals like lead chromate.

- **Adulteration in cereals and pulses**

Adulteration in cereals and pulses is a significant concern, as these foods form the foundation of the diet in many regions, especially in developing countries. Adulterants in cereals and pulses are often used to increase the weight or volume of the product, which can significantly affect the quality and safety of the food consumed. Common adulterants in cereals such as rice, wheat, and pulses like lentils, chickpeas, and beans include polished stones or pebbles to increase weight, broken grains or chalk powder to give the appearance of full, unbroken kernels, artificial colorants to enhance the look of the grain, such as using silver-colored paper for polishing rice, bran or sawdust mixed into flour to

make it appear bulkier. Metanil yellow is a synthetic dye commonly used as an adulterant in food, particularly to enhance the yellow color of pulses.

- **Adulteration in oils and fats**

The adulterants used in oils and fats are sometimes difficult to detect visually but can significantly impact the quality and safety of the product. Common adulterants in oils and fats include cheaper vegetable oils such as palm oil, soybean oil, or cottonseed oil, which are often mixed with premium oils like olive oil, mustard oil, or groundnut oil. One of the most dangerous adulterants found in mustard oil is argemone oil. This oil is toxic and can cause serious health problems, including a condition called dropsy, which leads to swelling, fluid retention, and heart damage. It is also linked to death in severe cases. In some cases, oils are adulterated with animal fats like lard or tallow to increase volume. These fats are unhealthy and can lead to cardiovascular diseases and other chronic conditions when consumed regularly. Other harmful substances such as mineral oils, sudan dyes, or used oils (such as those from industrial sources or leftover frying oil) are sometimes added to vegetable oils to enhance color or increase volume. These substances are not meant for human consumption and can cause long-term health problems, including cancer and liver damage.

- **Adulteration in tea and coffee**

These popular beverages, essential to many people's daily routine, are often adulterated with cheap, harmful substances to increase volume or enhance appearance, ultimately deceiving consumers. To make tea leaves look fresher and more appealing, synthetic dyes or artificial colors such as lead chromate or malachite green are sometimes added. Sometimes, older or leftover tea leaves are reused, cleaned, and mixed with fresh leaves. This not only lowers the quality but can introduce bacteria or fungi, making the tea unsafe to drink. Tea may be adulterated with stems, twigs, or other plant matter that are not part of the actual tea leaves. Fine saw dust or other powders are added to tea to increase weight or mask lower-quality leaves. Common adulterant in coffee is chicory, often added to coffee to increase its volume and reduce costs. While chicory is not harmful in moderate amounts, excessive quantities can reduce the purity and flavor of coffee. In some cases, non-edible starches, such as maize starch, are added to cheapen the product. Reusing old, used coffee grounds is a common form of adulteration. The coffee is mixed with stale grounds and resold, making it unsafe for consumption and affecting the flavor.

Table 9.1: Common Foods, Adulterants and Their Health Effects

Food Item	Common Adulterant	Health Effects
Milk	Water, detergent, starch, synthetic milk, urea	Digestive disorders, kidney damage, gastrointestinal infections, toxicity.
Milk Products	Vanaspati, starch	Digestive issues, reduced nutritional value, trans fat-related health problems.
Edible Oils	Mineral oil, argemone oil, cheaper oils	Cancer, dropsy, liver and heart damage, digestive issues.
Wheat Flour	Starch, chalk powder, soapstone	Digestive disorders, reduced nutritional quality, harmful long-term effects.
Pulses	Kesari dal, polished pulses, stones	Lathyrism (neurological disorder), abdominal pain, choking hazard.
Rice	Plastic pellets, polishing agents	Digestive issues, choking, and toxicity over time.
Tea Leaves	Used leaves, artificial color (iron fillings, lead chromate)	Poisoning, cancer, gastrointestinal and neurological issues.
Coffee	Tamarind seed powder, date seed powder, starch	Digestive issues, lower quality of coffee, long-term toxicity.
Spices (e.g., Turmeric, Chili, Coriander)	Lead chromate, Metanil Yellow, brick powder, sawdust	Anemia, cancer, kidney damage, liver damage.
Fruits	Calcium carbide (for ripening)	Cancer, abdominal pain, diarrhea, neurological disorders.
Vegetables	Malachite green, oxytocin (to enhance growth), artificial colors	Cancer, hormonal imbalance, and food poisoning.
Soft Drinks	Excess carbon dioxide, non-permitted synthetic dyes	Digestive issues, cancer, hyperactivity in children.
Ice Cream	Washing powder, synthetic milk, starch	Digestive disorders, kidney damage, and toxicity.
Honey	Glucose, sugar syrup	Diabetes, reduced immunity, and obesity.
Sugar	Washing powder, chalk powder, urea	Digestive problems, nausea, and food poisoning.
Salt	White powdered stone, chalk powder	Abdominal pain, reduced nutritional

		value, and digestive issues.
Meat	Water, formalin	Food poisoning, cancer, kidney and liver damage.
Fish	Formalin, ammonia	Cancer, food poisoning, and digestive discomfort.
Ice	Non-potable water	Cholera, diarrhea, and other water-borne diseases.

9.4 EVALUATION OF FOOD ADULTERANTS

The evaluation of food adulterants involves detecting the presence of harmful substances in food products through various physical, chemical, and laboratory tests. These methods range from simple home-based tests to advanced laboratory techniques. Below is a detailed overview of the common methods used to evaluate food adulterants:

- **Tea Leaves**

Adulterant: Iron Flakes

Detection Method: Place a small quantity (about 2 teaspoons) of the sample on a piece of paper and move a magnet over it. If iron flakes are present, they will cling to the magnet. This method can also be used to detect iron flakes in tea half-dust or iron filings in tea dust.

Adulterant: Leather Flakes

Detection Method: Create a paper ball and set it on fire. Sprinkle a small amount of the sample onto the burning ball. If leather flakes are present, they will emit a distinct odor of burnt leather.

Adulterant: Coal Tar Dye

Detection Method: Sprinkle a small amount (about 1 teaspoon) of the sample onto a moistened white blotting paper. Let it sit for 5 minutes, then remove the sample and inspect the paper. The appearance of colored spots indicates the presence of dye.

- **Coriander powder and Cumin Powder**

Adulterant: Saw Dust

Detection Method: Take a small amount (about half a teaspoon) of the sample and sprinkle it into a bowl of water. The genuine spice powder will settle at the bottom, while sawdust, if present, will float on the surface.

- **Green vegetables like Bitter Gourd, Green Chilli etc**

Adulterant: Malachite Green

Detection Method: Place a small portion of the sample on a piece of moistened white blotting paper. If the paper shows a color impression, it indicates the presence of malachite green or another low-cost artificial dye.

- **Arhar Pulse**

Adulterant: Kesari Pulse

Detection Method: Kesari pulses have a distinct wedge shape, and larger Kesari closely resembles Arhar (Tur). The two can be differentiated and separated through visual inspection.

- **Black Pepper**

Adulterant: Papaya Seeds

Detection Method: Papaya seeds, which are smaller in size and lack any distinctive smell, can be identified as adulterants in black pepper. This adulteration can be detected through visual inspection and by checking for the absence of the characteristic aroma of black pepper.

- **Rice and Wheat**

Adulterant: Earth, sand, grit, unhusked paddy, rice bran, talc, etc.

Detection Method: These adulterants may be detected visually and removed by way of sorting, picking, and washing.

- **Coffee powder**

Adulterant: Cereal starch

Detection Method: Take a small quantity of the sample and place it in a test tube. Add 3 ml of distilled water and heat the mixture using a spirit lamp to bring about a color change. Then, add 33 ml of a potassium permanganate and muriatic acid solution (in a 1:1 ratio) to decolorize the mixture. If a blue color forms after adding a drop of 1% aqueous iodine solution, it indicates adulteration with starch.

Adulterant: Powder of scorched persimmon stones

Detection Method: Take a small quantity of the sample and spread it on a moistened blotting paper. Carefully pour 3 ml of a 2% aqueous solution of sodium carbonate onto the sample. If a red coloration appears, it indicates the presence of powdered scorched persimmon stones in the coffee powder.

- **Jaggery**

Adulterant: Sodium bicarbonate

Detection Method: Place a small amount of the sample in a test tube. Add 3 ml of muriatic acid. If sodium carbonate or sodium bicarbonate is present, it will cause effervescence due to the release of carbon dioxide gas.

Adulterant: Metanil yellow colour

Detection Method: Take one-fourth of a teaspoon of the sample and place it in a test tube. Add 3 ml of alcohol and shake the tube vigorously to mix the contents. Then, add 10 drops of hydrochloric acid. If a pink coloration appears, it indicates the presence of metanil yellow dye in the jaggery.

- **Asafoetida**

Adulterant: Resin and colour

Detection Method: To test the purity of asafoetida, take a small portion of the sample and place it in a test tube. Add 3 ml of distilled water and gently shake the tube. Pure asafoetida dissolves rapidly, producing a milky white solution. However, if adulterated with chemical coloring, the mixture will take on a colored appearance. Another method to assess purity involves taking a small amount of asafoetida on the tip of a fork or forceps and placing it in the flame of a spirit lamp. Pure asafoetida burns quickly with a bright flame, leaving any impurities as residue.

- **Gram powder**

Adulterant: Kesari powder

Detection Method: Take a little amount of the sample in a test tube with 3 ml of distilled water. Add 3 ml of muratic acid. Immerse the tube in warm water. Check the tube after 15 minutes. A violet colouration indicates the presence of Kesari powder in Gram powder.

Adulterant: Metanil yellow colour

Detection Method: Take a small quantity of the sample in a test tube. Add 3 ml of alcohol. Shake the tube to mix up the contents thoroughly. Add 10 drops of hydrochloric acid in it. A pink colouration indicates adulteration of gram powder with metanil yellow.

- **Processed food, sweetmeat or syrup / Sweet potato**

Adulterant: Rhodamine B colour

Detection Method: The presence of Rhodamine B, a chemical color, in food is easily noticeable as it shines brightly under sunlight. For a more precise detection, take about half a teaspoon of the sample and place it in a test tube. Add 3 ml of carbon tetrachloride, then shake the tube thoroughly to mix the contents. If Rhodamine B is present, the mixture will turn colorless. Upon adding a drop of hydrochloric acid, the color will reappear, confirming the presence of the dye.

- **Green vegetables**

Adulterant: Malachite Green

Detection Method: Rub the outer green surface of a small part of the sample with liquid paraffin soaked cotton. The sample is adulterated if the white cotton turns green.

- **Dry red chilli**

Adulterant: Rhodamine B colour

Detection Method: Take a red chilli from the sample and rub the outer surface with a piece of cotton soaked in liquid paraffin. The sample is adulterated if the cotton becomes red.

9.5 GENETICALLY MODIFIED FOODS

GM Foods (Genetically Modified Foods) are foods that have been altered through genetic engineering to introduce new traits or characteristics. This involves modifying the DNA of plants, animals, or microorganisms to achieve desired outcomes, such as improved resistance to pests, enhanced nutritional content, or better tolerance to environmental conditions. For example, GM crops might be engineered to withstand herbicides, produce higher yields, or have higher vitamin content. Genetic modifications are done using advanced techniques like gene editing or recombinant DNA technology, and GM foods are commonly found in products like corn, soybeans, cotton, and rice. The first genetically modified (GM) plant was produced in 1983, using an antibiotic-resistant tobacco plant. China was the first country to commercialize a transgenic crop in the early 1990s with the

introduction of virus resistant tobacco. In 1994, the transgenic 'Flavour Saver tomato' was approved by the Food and Drug Administration (FDA) for marketing in the USA. The best known example of this is the use of B.t. genes in corn and other crops. B.t., or *Bacillus thuringiensis*, is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. B.t. crystal protein genes have been transferred into corn, enabling the corn to produce its own pesticides against insects such as the European corn borer.

Genetically-modified foods have the potential to eliminate or reduce malnutrition problems, help protect and preserve the environment by increasing yield and reducing the use of chemical pesticides and herbicides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation and international policies. There are numerous controversies surrounding GM foods, including concerns about their safety, the need for labeling, and their role in addressing world hunger both now and in the future. Issues also arise regarding intellectual property, market dynamics, environmental impact, and the broader role of GM crops in industrial agriculture. Concerns about the potential unintended harm to the environment, health risks for consumers, and the benefits of recombinant technology are significant when it comes to pest-resistant and herbicide-resistant plants. Additionally, the evolution of resistant pests and weeds, often referred to as "superbugs" and "superweeds," poses further challenges. Health risks associated with GM foods include concerns about toxins, allergens, and genetic hazards. Potential risks fall into three main categories: the genes inserted into the organism and their expression products, secondary effects of gene expression, and unintended changes caused by gene insertion. In the first category, it is not the transferred gene itself that may pose a risk, but rather the effects of the gene's expression and its product. New proteins created through genetic modification may lead to unexpected allergic reactions. For example, genetically modified bean plants designed to increase certain amino acids were discarded after it was discovered that the new protein they produced triggered allergic reactions. Special attention should be given to foods that contain genes from common allergens such as milk, eggs, nuts, wheat, legumes, fish, mollusks, and crustaceans.

9.6 NANO PARTICLES IN FOOD

Nanoparticles are extremely tiny particles that are so small you can only see them with special microscopes. They are between 1 and 100 nanometers in size, a nanometer is a million times smaller than the tip of a pencil! Because of their small size, nanoparticles behave differently from bigger materials. For example, they might be more reactive, stronger, or have special properties like the

ability to change color or conduct electricity better. They are used in many fields, like medicine, electronics, and even food, to improve products or create new ones. Nanoparticles, which are materials with dimensions smaller than 100 nanometers, are increasingly being used in the food industry for their unique physical, chemical, and biological properties. These particles can improve the texture, flavor, shelf life, and nutritional content of food products while also providing innovative solutions for food packaging and safety.

Nanoparticles have numerous applications in the food industry, enhancing food quality, safety, and shelf life. They are used to improve nutrient delivery, making vitamins, minerals, and other nutrients easier for the body to absorb. In food packaging, nanoparticles like nanoclays and nano-silver strengthen materials, block moisture and oxygen, and prevent bacterial growth, extending product freshness. Smart packaging with nanosensors can monitor food spoilage or contamination in real time. Additionally, nanoparticles enhance food additives, providing better texture, flavor, and color stability. Some commonly used nanoparticles include silicon dioxide (SiO_2) which is used as an anti-caking agent in powdered foods like spices, coffee, and powdered milk to prevent clumping; titanium dioxide (TiO_2) commonly used as a whitening agent in products like candy, chewing gum, and sauces; silver nanoparticles (AgNPs) are incorporated into food packaging for their antimicrobial properties, preventing bacterial growth and extending shelf life; zinc oxide (ZnO) are being used in packaging materials to block UV light and provide antimicrobial effects; carbon nanotubes are being applied in sensors for detecting contaminants, spoilage, or toxins in food; chitosan nanoparticles which are derived from natural sources and used as antimicrobial coatings for fruits, vegetables, and other perishable foods.

The use of nanoparticles in food raises several safety concerns due to their small size and unique properties. Nanoparticles can cross biological barriers, such as the intestinal wall, and accumulate in tissues, potentially leading to unknown health effects. Some nanoparticles, like titanium dioxide and silver, may generate reactive oxygen species (ROS), causing oxidative stress, inflammation, or even DNA damage. Additionally, their long-term effects on the gut microbiome and overall health remain unclear due to limited research. Environmental concerns also arise as nanoparticles used in packaging can persist in ecosystems, entering the food chain affecting plants, animals, and eventually humans and causing unintended consequences. Determining safe levels of exposure to nanoparticles is critical for setting regulatory limits. Comprehensive toxicological studies are needed to evaluate nanoparticles' behavior in the human body, including absorption, distribution, metabolism, and excretion. The lack of

standardized testing methods and regulations further complicates risk assessment, highlighting the need for more research and strict guidelines to ensure their safe use in the food industry.

9.7 FOOD INSPECTION AND SAFETY MEASUREMENTS

Food inspection and safety measures are critical to ensuring that food products are safe for consumption, free from harmful contaminants, and meet established quality standards. These practices are vital to protect public health and maintain consumer confidence in the food industry. Food inspection and safety measures are essential for preventing foodborne illnesses, and maintaining food quality. Stringent regulations, proper food handling, continuous monitoring, and consumer education all play vital roles in maintaining the integrity of the food supply chain and ensuring that food products are safe for consumption. Food inspection involves checking food products for quality, safety, and compliance with regulations. It may include:

- **Visual Inspection:** Checking for signs of contamination, spoilage, foreign matter, or packaging issues. For example, checking for signs of insect infestation or discoloration in fruits and vegetables.
- **Physical Testing:** Involves assessing the physical quality of food, such as texture, color, shape, and size. For example, determining the purity of spices or checking for the presence of adulterants like starch in coffee powder.
- **Chemical Testing:** Checking for harmful chemicals or adulterants in food, such as pesticides, heavy metals, food additives, and preservatives beyond permissible limits.
- **Microbiological Testing:** Testing food products for harmful microorganisms such as bacteria, viruses, and fungi, which can cause foodborne illnesses (e.g., *Salmonella*, *Listeria*, *E. coli*).
- **Hygiene Inspection:** Ensuring that food is processed, packaged, and stored under hygienic conditions. This includes checking for cleanliness in food processing plants and storage facilities to prevent contamination.

Food safety measures are essential practices and guidelines designed to ensure that food is safe for consumption, free from contamination, and properly handled throughout the food production and consumption process. These measures aim to protect public health by preventing foodborne illnesses and maintaining the quality and integrity of food products. Some key food safety measures are:

- **Hygiene and Sanitation**

Food handlers should wash their hands thoroughly before handling food, especially after using the restroom, touching raw foods, or handling waste. Wearing clean clothes, gloves, and hairnets is also essential. The workspaces like kitchens, food processing areas, and storage spaces must be cleaned and sanitized regularly to prevent the buildup of harmful bacteria and contaminants. Food waste, packaging materials, and other refuse should be disposed of in a manner that does not contaminate food.

- **Temperature Control**

Perishable foods should be stored at appropriate temperatures to prevent bacterial growth. This includes refrigerating perishable items at 4°C (39°F) or lower and freezing them at -18°C (0°F) or lower. Foods that are cooked and kept warm (e.g., at buffets or food service) should be held at a temperature of at least 60°C (140°F) to prevent bacterial growth. The temperature range between 4°C (39°F) and 60°C (140°F) is known as the "danger zone," where bacteria multiply rapidly. Foods should not be left at room temperature for extended periods.

- **Cross-Contamination Prevention**

Raw foods, especially meats, should be kept separate from cooked or ready-to-eat foods to prevent cross-contamination. Different utensils, cutting boards, and kitchen tools should be used for raw and cooked foods to avoid cross-contact. Raw foods should be even stored separately in the refrigerator, typically on the bottom shelf to prevent drips onto other foods.

- **Food Handling and Packaging**

Frozen foods should be thawed safely, either in the refrigerator, in cold water, or in the microwave. Thawing food at room temperature can allow bacteria to multiply. Foods should be packaged in clean, food-grade materials. The packaging should be sealed tightly to prevent contamination. Always check food expiration dates to ensure the food is safe to consume. Discard foods that have passed their expiration dates or are showing signs of spoilage.

- **Regular Food Safety Inspections**

Food businesses should undergo regular inspections by food safety authorities (like the Food Safety and Standards Authority of India – FSSAI) to ensure compliance with food safety standards.

Food businesses should also have internal monitoring and inspection systems in place to continuously check the quality and safety of food products. A preventive approach to food safety, the HACCP system focused on identifying potential hazards at every stage of the food production process, from raw material handling to consumption should be in place. It sets critical control points where safety measures must be applied to prevent contamination.

- **Regular Food Safety Testing**

- **Microbiological Testing:** Foods should be tested regularly for harmful microorganisms such as Salmonella, Listeria, *E. coli*, and other pathogens that can cause foodborne illnesses.
- **Chemical Testing:** Food products should be tested for harmful chemicals like pesticides, heavy metals, and preservatives to ensure they are within permissible limits.
- **Adulterant Detection:** Regular checks for food adulteration and the presence of harmful additives are essential to ensure that food products meet safety standards.

9.8 SUM UP

This unit has apprised you about how common adulterants such as toxic chemicals, artificial colorants, and harmful preservatives can lead to foodborne illnesses, allergic reactions, and long-term health issues like cancer and neurological disorders. We have also learnt simple methods for detection of adulterants in food. Through this unit, you will be able to evaluate the potential health risks associated with the consumption of foods containing nanoparticles and genetically modified foods. The unit helped us to recognize the importance of consumer education in identifying unsafe food products. Addressing these concerns is vital to safeguarding public health and ensuring the safety of global food systems.

9.9 CHECK YOUR PROGRESS

1. Define:

a) Food adulteration

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b) Food adulterant

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c) Genetically modified food

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2. Explain the method for detection of following adulterants:

a) Malachite green in vegetables

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b) Starch in coffee powder

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c) Iron flakes in tea leaves

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d) Metanil yellow in spices

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3. Explain the types of food inspection.

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4. Write a short note on food safety measurements required in a food plant.

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5. List some nanoparticles and their applications in food industry.

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मुक्त विश्वविद्यालय, प्रयागराज

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FOOD SAFETY AND QUALITY CONTROL

BLOCK-4 INTRODUCTION TO FOOD BORNE DISEASES, PROCESSING CONTAMINANTS AND FOOD LABELLING		
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BLOCK-IV INTRODUCTION TO FOOD BORNE DISEASES, PROCESSING CONTAMINANTS AND FOOD LABELLING

Food safety is essential for public health, and Block IV covers three key units i.e. foodborne diseases, processing contaminants, and food labeling. Foodborne diseases result from consuming contaminated food, often due to bacteria, viruses, or toxins. Processing contaminants, such as acrylamide or nitrosamines, can form during food production, posing health risks. Accurate food labeling ensures consumers have vital information about ingredients, allergens, and nutritional content. Understanding these topics helps in preventing illnesses, promoting safer food practices, and ensuring compliance with food safety regulations.

Unit X provides an in-depth understanding of various foodborne diseases, focusing on the bacteria, viruses, and fungi responsible for them. It introduces the concept of food poisoning and differentiates between food infection and food intoxication. Learners will gain insights into the organisms involved in foodborne illnesses, their symptoms, sources of contamination, and the types of foods most commonly associated with these conditions. The unit also explores the mycotoxins produced by fungal growth in food and their impact on human health. Furthermore, it highlights effective methods and best practices for preventing foodborne illnesses, ensuring food safety, and protecting public health.

Unit XI provides an in-depth examination of common processing contaminants in food and their implications for health and safety. It explores how various food processing techniques, such as deodorization, high-temperature cooking, and industrial refining, can contribute to the formation of these contaminants. Learners will gain insights into the potential health effects associated with consuming foods containing processing by-products. Additionally, it discusses effective strategies for minimizing the presence of these contaminants in food, ensuring safer production practices and improved food safety standards.

Unit XII deals with concept of food labeling, food fraud, and food authenticity which are integral to modern food safety and quality control systems. The unit unfolds the concept of food fraud, which includes deceptive practices such as mislabeling, adulteration, and substitution, not only compromises public health but also erodes consumer trust in the food supply chain. On the other hand, it also explains food authenticity which ensures that products are genuine, meet expected quality standards, and uphold fair trade practices, thereby safeguarding consumers from health risks and promoting transparency. This unit delves into the importance of food labeling, the regulatory frameworks governing it, the implications of food fraud, and the advanced methods used to verify food authenticity.

UNIT-X FOOD BORNE DISEASES

Structure

- 10.1 Introduction
- 10.2 Food Borne Diseases
- 10.3 Bacterial Diseases
 - 10.3.1 Salmonellosis
 - 10.3.2 Campylobacteriosis
 - 10.3.3 Listeriosis
 - 10.3.4 Staphylococcal Intoxication
 - 10.3.5 *Clostridium perfringens* Foodborne Illness
 - 10.3.6 *E. coli* Hemorrhagic Colitis
- 10.4 Viral Diseases
- 10.5 Zoonotic Food Borne Parasites
- 10.6 Mycotoxins
- 10.7 Mushroom Poisoning
- 10.8 Prevention of Food Borne Illness
- 10.9 Sum Up
- 10.10 Check Your Progress

10.1 INTRODUCTION

This unit focuses on various foodborne diseases, providing a comprehensive overview of the bacteria, viruses and fungi responsible for them. It explores the concept of food poisoning and distinguishes between food infection and food intoxication. You will learn about the organisms involved in different

foodborne illnesses, their symptoms, sources of contamination, and the types of foods commonly associated with them. Additionally, the unit covers the various mycotoxins produced by fungal growth in foods and delves into effective methods for preventing foodborne illnesses.

Objectives

Learning this unit will make you:

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

10.2 FOOD BORNE DISEASES

Foodborne illnesses are health conditions resulting from the consumption of contaminated food or beverages. These diseases are caused by a variety of microorganisms, such as bacteria, viruses, parasites, and toxins produced by these pathogens. The illness occurs when these pathogens infect the host's body, damaging tissues and cells during their growth and sometimes releasing harmful toxins. The symptoms of foodborne illnesses range from mild to severe and can affect people of all ages. Common symptoms include nausea, vomiting, diarrhea, abdominal pain, fever, and dehydration. In severe cases, foodborne illnesses may lead to critical health issues like kidney failure, meningitis, or even death. Contamination of food can happen at any stage of the food chain, including production, processing, transportation, storage, and preparation. Certain foods are particularly vulnerable to contamination, such as raw or undercooked meat, poultry, fish, shellfish, and improperly washed fruits and vegetables.

Preventing foodborne illnesses requires proper food handling and preparation. This includes washing hands and surfaces thoroughly, cooking food to the correct temperature, and storing food at safe temperatures. Adhering to these food safety practices significantly reduces the risk of contamination and ensures that food is safe for consumption. Beyond individual efforts, regulatory agencies play a vital role in maintaining food safety. Governments worldwide enforce food safety standards and regulations, requiring food producers and handlers to comply with these measures.

Regular inspections and monitoring of food production facilities help detect potential sources of contamination and prevent outbreaks of foodborne illnesses.

Foodborne illnesses can be categorized into two types:

- **Foodborne infection:** This occurs when individuals consume food contaminated with pathogens such as bacteria, parasites, or viruses. These pathogens infect the body, often targeting the intestinal tract and causing disease.
- **Foodborne intoxication:** This occurs when people ingest food containing pre-formed toxins produced by pathogens like bacteria, molds, mushrooms, or marine organisms. In these cases, the pathogens themselves may no longer be present in the food, but their toxins cause the illness.

10.3 BACTERIAL DISEASES

10.3.1 Salmonellosis

Salmonellosis is a foodborne infection caused by consuming foods contaminated with *Salmonella* bacteria, primarily *Salmonella enteritidis* and *Salmonella typhimurium*, which together account for nearly half of all cases. After ingestion, these bacteria can multiply in the intestines, causing illness that varies in severity depending on the bacterial dose, the host's immunity, and the specific strain involved. Symptoms, which typically appear within 8 to 72 hours, include headache, diarrhea, abdominal pain, nausea, fever, chills, and vomiting, lasting four to seven days. High-risk groups include infants, young children, pregnant women, the elderly, and individuals with weakened immunity. Foods commonly linked to contamination include eggs, salads, poultry, beef, processed meats, fish, dairy products, and raw sprouts, with contamination possible at any stage from production to consumption. *Salmonella* spreads through direct or indirect contact with feces or intestinal contents of animals or humans, such as unwashed hands after using the toilet or during meat processing. The bacteria grow between 41°F and 113°F, are destroyed by cooking to 160°F, and survive refrigeration or freezing, resuming growth when food reaches room temperature. Preventive measures include cooking foods thoroughly, refrigerating perishable items promptly, maintaining proper hygiene, and cleaning surfaces and utensils after handling raw foods, significantly reducing the risk of infection.

10.3.2 Campylobacteriosis

Campylobacteriosis, or *Campylobacter enteritis*, is an infection caused by consuming food or water contaminated with *Campylobacter jejuni*. This bacterium is commonly found in the intestinal tracts of healthy animals, especially chickens, and in untreated surface water. Common sources of human infection include raw milk, undercooked chicken, raw hamburger, raw shellfish, and non-chlorinated water. *C. jejuni* thrives in low-oxygen environments, is easily destroyed by heat (120°F), and is inhibited by acid, salt, and drying, while it cannot grow at temperatures below 85°F. Symptoms such as diarrhea, nausea, abdominal cramps, muscle pain, headache, and fever typically appear two to ten days after consuming contaminated food and last two to seven days, though complications can extend the duration. Rare complications include urinary tract infections, reactive arthritis, meningitis, recurrent colitis, acute cholecystitis, and Guillain-Barré syndrome, with deaths being extremely rare. Preventive measures include pasteurizing milk, avoiding contamination after pasteurization, thoroughly cooking meat, poultry, and fish, and preventing cross-contamination between raw and ready-to-eat foods.

10.3.3 Listeriosis

Prior to the 1980s, listeriosis, caused by *Listeria monocytogenes*, was primarily a veterinary concern, linked to abortions and encephalitis in sheep and cattle. However, due to its wide environmental distribution, ability to survive adverse conditions, and capacity to grow at refrigeration temperatures, *L. monocytogenes* is now recognized as a significant foodborne pathogen. The bacterium is frequently carried by humans and animals and can grow within a pH range of 4.4 to 9.6. It is salt-tolerant, relatively resistant to drying, but easily destroyed by heat, growing best between 32°F and 113°F. Listeriosis mainly affects newborns, pregnant women, the elderly, and individuals with weakened immune systems. In healthy, non-pregnant individuals, it may present as a mild illness with symptoms such as fever, headaches, nausea, and vomiting. In pregnant women, intrauterine or cervical infections can lead to spontaneous abortion or stillbirth, while infants born alive may develop meningitis. The mortality rate in diagnosed cases is 20–25%. The incubation period ranges from a few days to several weeks. Recent outbreaks have been linked to raw milk, soft cheeses made from raw milk, and raw or refrigerated ready-to-eat meat, poultry, or fish products. Preventive measures include maintaining proper sanitation, ensuring rapid turnover of refrigerated ready-to-eat foods, pasteurizing milk, avoiding post-pasteurization contamination, and thoroughly cooking food.

10.3.4 Staphylococcal Intoxication

Staphylococcus bacteria are commonly found on the skin, in the nose, and in the throat of most individuals, with people suffering from colds or sinus infections often acting as carriers. Infected wounds, pimples, boils, and acne are particularly rich sources of these bacteria. Staphylococcus is also prevalent in untreated water, raw milk, and sewage. When these bacteria enter warm food and multiply, they produce a toxin that causes illness. This toxin cannot be detected by taste or smell and is heat-resistant, meaning it can survive cooking temperatures, even if the bacteria themselves are killed at 120°F. Commonly implicated foods include protein-rich items like ham, processed meats, tuna, chicken, sandwich fillings, cream fillings, potato and meat salads, custards, milk products, and creamed potatoes, especially those frequently handled during preparation. Symptoms of staphylococcal intoxication—such as abdominal cramps, vomiting, severe diarrhea, and exhaustion—typically appear within 1 to 8 hours of consuming contaminated food and last for 1 to 2 days. Although rarely fatal, the illness can be severe. To prevent contamination, ensure food is handled hygienically, keep it either hot (above 140°F) or cold (below 40°F) during serving, and refrigerate or freeze leftovers promptly to inhibit bacterial growth.

10.3.5 *Clostridium perfringens* foodborne illness

Clostridium perfringens, a bacterium in the same genus as *Clostridium botulinum*, causes a foodborne illness that is generally less severe than botulism, with very few reported fatalities. Spores of *C. perfringens* are found in soil, nonpotable water, unprocessed foods, and the intestines of animals and humans. Meat and poultry are commonly contaminated with these spores during processing. Some *C. perfringens* spores are highly heat-resistant, surviving boiling temperatures for four hours or more. Cooking also creates conditions that promote spore germination by driving off oxygen, killing other microorganisms, and heat-shocking the spores. Once the spores germinate, they thrive in warm, moist, protein-rich environments with little or no oxygen, such as when meats are held at room temperature for extended periods or large pots of food, like gravy or meat, cool too slowly in the refrigerator. Foods most commonly linked to *C. perfringens* illness include cooked, cooled, or reheated meats, poultry, stews, casseroles, meat pies, and gravies. Symptoms typically occur within 8 to 24 hours after consuming contaminated food and include acute abdominal pain, diarrhea, nausea, vomiting, and fever.

10.3.6 *E. coli* Hemorrhagic Colitis

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

10.4 VIRAL DISEASES

Foodborne viral infections are caused by consuming food or water contaminated with harmful viruses. These viruses are particularly resilient to environmental factors such as low pH (acidity) and heat, allowing them to remain infective in food and water for extended periods, sometimes lasting over a month. These viruses typically originate in the intestines of humans and animals, and they are primarily spread through fecal contamination or other body fluids. Contamination can occur at various points in the food production process, particularly when hygiene practices are poor or when food comes into contact with animal waste or sewage. Certain foods are more prone to viral contamination, including shellfish harvested from waters near sewage outlets, undercooked meats, and fruits and vegetables grown in soils fertilized with animal waste. The most common foodborne viral infections include gastroenteritis and hepatitis, both of which are caused by specific viruses. Notably, *Norovirus* and *Hepatitis A* virus (HAV) are the primary culprits, although other viruses like *enterovirus*, *sapovirus*, *rotavirus*, *astrovirus*, *adenovirus*, and *Hepatitis E* have also been linked to foodborne illnesses.

Norovirus is one of the most widespread foodborne viruses, causing gastroenteritis with symptoms such as diarrhea, vomiting, fever, headaches, and abdominal pain. It is highly contagious,

and even a small number of virus particles (as few as 10–100) can cause illness. The symptoms typically develop within 12–48 hours after exposure, and the illness usually lasts 1–3 days. However, asymptomatic individuals or those who are immunosuppressed may shed the virus for up to 8 weeks, making it a persistent threat in food handling environments. Norovirus spreads primarily through person-to-person transmission, especially via the fecal-oral and vomit-oral routes. It can also be transmitted indirectly through contaminated food, water, surfaces, or the environment. Foods most commonly associated with norovirus outbreaks include ready-to-eat items such as leafy vegetables, herbs, and berries, as well as foods handled after cooking.

Rotavirus, particularly *Rotavirus A*, is another significant cause of viral gastroenteritis, especially among infants and young children. This virus is responsible for severe watery diarrhea, vomiting, fever, and dehydration. Symptoms usually appear 1–2 days after infection, starting with vomiting followed by several days of diarrhea. The disease is usually self-limiting, but in young children, dehydration can be severe and may require hospitalization. Rotavirus is transmitted through contact with contaminated surfaces, objects, or food, as well as through direct person-to-person contact. Outbreaks of rotavirus gastroenteritis are common in both children and adults, especially in places where sanitation is poor. *Rotavirus* is the leading cause of severe diarrhea in children worldwide, and while most children recover, it is responsible for an estimated 200,000 deaths annually, primarily in developing countries. Prevention primarily focuses on vaccination, maintaining good hygiene practices, and ensuring proper rehydration to avoid severe dehydration.

Hepatitis A is another viral infection that can be transmitted through contaminated food and water. It affects the liver, causing symptoms such as fever, headache, nausea, abdominal pain, diarrhea, and jaundice. Although hepatitis A infections are often self-limiting and resolve on their own, they can sometimes lead to severe liver damage or even liver failure in rare cases. Hepatitis A is responsible for approximately 50% of all hepatitis cases worldwide. The virus is typically transmitted through the fecal-oral route, often due to consumption of food or water contaminated with feces from infected individuals. Foods commonly associated with *Hepatitis A* outbreaks include shellfish, unpasteurized dairy products, fruits, and vegetables that have been contaminated with sewage or untreated water. Preventive measures include proper sanitation, vaccination, and avoiding food from questionable sources.

In addition to norovirus, rotavirus, and hepatitis A, other viruses such as *enterovirus*, *sapovirus*, *astrovirus*, and *adenovirus* can also be transmitted through food and water. These viruses can cause

gastrointestinal symptoms, similar to those caused by norovirus and rotavirus, and may affect people with weakened immune systems more severely. The global potential for these foodborne viruses to spread is heightened due to unrestricted travel and the international movement of food products. This makes controlling outbreaks more challenging, especially in regions with inadequate food safety regulations or poor sanitation practices. Furthermore, detecting and quantifying viral contamination in food and water remains a difficult task due to the low levels of the virus that may be present, making it harder to monitor and prevent outbreaks effectively.

10.5 ZOONOTIC FOOD BORNE DISEASES

Zoonotic diseases are infections that can be transmitted between animals and humans, with severity varying from mild to life-threatening in humans. Foodborne zoonotic diseases occur when food or water is contaminated by pathogenic microorganisms, such as bacteria, viruses, or parasites. These pathogens typically enter the body through the gastrointestinal tract, where the first symptoms are often observed. Many of these microorganisms are naturally found in the intestines of healthy food-producing animals. The risk of contamination exists at every stage from farm to fork, necessitating prevention and control measures throughout the entire food chain. Food becomes contaminated in zoonotic diseases through several pathways, primarily linked to the handling, processing, and consumption of animal products, as given below:

- **Animal to Food Direct Contamination**

Zoonotic pathogens often reside in the intestines of animals. If animal manure or feces come into contact with food (during slaughter, butchering, or handling), pathogens like *Salmonella*, *E. coli*, or *Campylobacter* can contaminate the meat or produce. During the handling or transportation of animals, pathogens can be transferred to food products, especially in improper conditions where sanitation is lacking. Milk from infected cows or improperly handled milk products can transmit diseases like *Brucellosis* or *Tuberculosis*.

- **Processing and Slaughter**

At slaughter houses, processing plants, or during food handling in kitchens, raw animal products can contaminate ready-to-eat foods. This can happen through shared equipment, surfaces, or improper storage practices. When animals are not slaughtered or dressed properly, parts of the intestines or fecal matter can contaminate meat, leading to the spread of bacteria or viruses.

- **Improper Food Handling**

If raw meat or seafood is not properly separated from other food items, or if utensils are not sanitized after being used on raw animal products, pathogens can spread to ready-to-eat food through cross-contamination. Storing raw meat at incorrect temperatures or not refrigerating food promptly can lead to bacterial growth, increasing the chances of contamination.

- **Infected Animal Products:**

Eating undercooked meat, poultry, seafood, or eggs increases the risk of consuming pathogens such as *Salmonella*, *Toxoplasma*, or *Trichinella*. Products like raw eggs or unpasteurized dairy can harbor zoonotic pathogens like *Salmonella* or *Listeria*, leading to contamination when consumed without proper cooking or pasteurization.

The most common foodborne diseases are caused by *Campylobacter*, *Salmonella*, *Yersinia*, *E. coli* and *Listeria*. These microorganisms have already been discussed in section 10.3. Some of the other zoonotic food borne diseases are discussed below:

- **Brucellosis:**

It is a bacterial infection caused by *Brucella* species, which are primarily found in livestock such as cattle, sheep, goats, and pigs. The disease can be transmitted to humans through direct contact with infected animals or consumption of unpasteurized dairy products and undercooked meat from infected animals. *Brucella* bacteria are able to infect a variety of animals, and in humans, brucellosis often presents as a chronic illness with a wide range of symptoms. Humans typically contract brucellosis when they consume contaminated milk, cheese, or meat products, particularly in regions where livestock are not vaccinated against the disease. The bacteria can enter the human body through cuts in the skin, mucous membranes, or ingestion, typically through food or direct exposure to infected animals or their secretions. People who work closely with livestock, such as farmers, veterinarians, or slaughterhouse workers, are at a higher risk for contracting brucellosis.

Once inside the body, *Brucella* bacteria invade and replicate in various organs, including the liver, spleen, bone marrow, and reproductive organs. Symptoms of brucellosis typically include fever, chills, excessive sweating, muscle and joint pain, fatigue, headache, and swollen lymph nodes. In severe cases, it can lead to complications like arthritis, endocarditis (infection of the heart valves), and neurological problems such as meningitis. Preventive measures for brucellosis include vaccination of livestock, pasteurization of dairy products, proper handling and cooking of meat, and the use of

protective gear for individuals at high risk. In many countries, regulatory programs to control brucellosis in animals have been established, which has helped to reduce the number of cases in both animals and humans.

- **Trichinosis**

Trichinosis is a parasitic infection caused by the roundworm *Trichinella* species, primarily *Trichinella spiralis*. The disease is typically contracted by consuming raw or undercooked meat, particularly pork or wild game (like bear, boar, or deer), that is infected with the larvae of the parasite. When a person consumes contaminated meat, the larvae are released in the stomach and then migrate to the small intestine, where they mature into adult worms. The female worms release larvae, which travel through the bloodstream and settle in muscle tissue. Once in the muscles, they encyst, and the cycle continues if the meat is consumed by another animal. The symptoms of trichinosis can vary depending on the number of larvae ingested and the severity of the infection. In mild cases, symptoms may not appear or may be very mild, while in more severe cases, the disease can cause significant illness. Symptoms typically begin 1–2 days after consumption of contaminated meat and can last for weeks. Early symptoms include abdominal pain, diarrhea, nausea, and vomiting. As the larvae move into muscle tissue, more serious symptoms can develop, such as muscle pain, swelling, weakness, fever, headache, and difficulty breathing. In severe cases, the infection can cause inflammation of the heart and brain, leading to life-threatening complications.

- **Toxoplasmosis**

It is a parasitic infection caused by *Toxoplasma gondii*, a protozoan parasite that can infect most warm-blooded animals, including humans. The infection can be transmitted to humans through consumption of undercooked or raw meat, particularly pork, lamb, and venison, which may harbor the cysts of the parasite. Toxoplasmosis often causes no symptoms or only mild flu-like symptoms in healthy individuals. However, in some cases, the infection can cause swollen lymph nodes, muscle aches, and mild fever. Severe symptoms, such as eye problems (including blurred vision and eye pain) or neurological issues (such as headaches, confusion, seizures, or motor problems), can occur if the infection spreads to the brain or eyes, especially in individuals with weakened immune systems. Toxoplasmosis poses a serious risk to pregnant women, as the parasite can cross the placenta and infect the fetus. Congenital toxoplasmosis can cause serious birth defects, including brain damage, eye problems, and developmental delays. If a woman contracts toxoplasmosis during pregnancy, there is a risk of miscarriage or stillbirth, and the baby may be born with severe complications. However, if the

infection is detected early in the pregnancy, treatment with antiparasitic medications can reduce the risk of transmission to the fetus and prevent long-term complications.

- **Cryptosporidiosis**

It is a diarrheal disease caused by the protozoan parasite *Cryptosporidium*. It is one of the most common waterborne diseases worldwide and is primarily spread through the ingestion of contaminated water, but can also be transmitted through contaminated food, surfaces, or direct contact with infected animals or people. The parasite affects the intestines and can lead to symptoms ranging from mild to severe, particularly in individuals with weakened immune systems. *Cryptosporidium* is a microscopic parasite that produces oocysts, which are excreted in the feces of infected animals or humans. These oocysts are highly resistant to chlorine and can survive in water for extended periods. The symptoms of cryptosporidiosis typically appear 2 to 10 days after exposure to the parasite and can last for a few days to several weeks, depending on the severity of the infection and the health of the individual. Common symptoms include diarrhea (which may be watery and severe), stomach cramps or bloating, nausea and vomiting, fatigue, fever, loss of appetite and weight loss.

- **Avian Influenza**

Commonly referred to as "bird flu", it is a viral infection that primarily affects birds, but in some cases, it can also spread to humans and other animals. The disease is caused by influenza A viruses, which are divided into subtypes based on two proteins on the virus's surface—hemagglutinin (H) and neuraminidase (N). The most concerning strains of avian influenza are H5N1, H7N9, and H5N8, as they have shown the potential to cause severe illness and death in humans. Avian influenza is primarily spread through direct contact with infected birds or their droppings, saliva, nasal secretions, or contaminated surfaces. Humans can also become infected by consuming undercooked poultry products (though cooking at proper temperatures kills the virus) or through close contact with infected poultry, especially in areas where biosecurity measures are inadequate. In humans, avian influenza infection typically results in flu-like symptoms, however in severe cases, the infection can progress to pneumonia, acute respiratory distress syndrome (ARDS), organ failure, and death. Complications may also include eye infections, conjunctivitis, and other serious conditions. The severity of symptoms depends on the strain of the virus and the individual's overall health. Avian influenza outbreaks can have a significant economic impact on the poultry industry, leading to mass culling of infected birds and disruptions to the food supply chain.

10.6 MYCOTOXINS

Mycotoxins are fungal metabolites that can cause illness or death when ingested, inhaled, or absorbed through the skin by humans, domestic animals, and birds. While only a small numbers of fungal compounds are classified as mycotoxins; those that have been proven to cause harm. These toxins are produced during fungal growth, but their formation depends on environmental factors like temperature and water activity (aw), which must be conducive to fungal growth. Therefore, mycotoxin production can occur at any stage of food production, including growing, harvesting, drying, or storing food commodities. While mycotoxins can also be present in processed foods, they are most concerning when found in raw commodities like grains and nuts. Once formed, mycotoxins are chemically stable and remain in food even after the fungi that produced them are destroyed. The molecular structures of mycotoxins are diverse, leading to a wide range of health effects on humans and animals. These effects can include neurotoxicity, teratogenicity (birth defects), nephrotoxicity (kidney damage), hepatotoxicity (liver damage), immunosuppression, and even cancer. Some of the most important and studied mycotoxins include aflatoxins, ochratoxin A, fumonisins, deoxynivalenol, and zearalenone.

Aflatoxins are a group of toxic and carcinogenic compounds produced by fungi, particularly *Aspergillus flavus* and *Aspergillus parasiticus*. These fungi thrive in warm and humid conditions, contaminating a wide range of crops, including peanuts, corn, cottonseed, and tree nuts. Aflatoxins are classified into different types, with aflatoxin B1 being the most toxic and carcinogenic. Aflatoxin B1 is the most commonly found type in contaminated food. Consumption of food contaminated with aflatoxins can lead to serious health issues, such as liver damage, immune suppression, and an increased risk of liver cancer. Young children and individuals with weakened immune systems are particularly vulnerable to the harmful effects of aflatoxins. Control measures for aflatoxin contamination include proper agricultural practices, such as crop management and appropriate storage conditions, along with food processing techniques like sorting and dehulling to remove contaminated parts. The use of fungicides can also help prevent fungal growth and reduce the risk of aflatoxin contamination. Regulatory agencies and food manufacturers worldwide have set strict limits on the allowable levels of aflatoxins in food, although these limits can vary depending on the type of food and the region in which it is produced and consumed.

Ochratoxin is a toxic and carcinogenic compound produced by various species of fungi, most notably *Aspergillus ochraceus* and *Penicillium verrucosum*. These fungi can contaminate a wide range of crops, including cereal grains, coffee, and grapes. Like aflatoxins, ochratoxins pose significant

health risks to humans. Chronic exposure to ochratoxins has been associated with kidney damage and an increased risk of kidney cancer. Additionally, ochratoxin has been shown to have immunosuppressive and genotoxic properties, meaning it can damage DNA and increase the likelihood of developing cancer. The risk of ochratoxin contamination is particularly high in certain food products, such as wine and coffee, where fungal growth is common. It can also affect stored grains, especially under warm and humid conditions that promote fungal growth. Preventing ochratoxin contamination involves a combination of good agricultural practices, proper storage techniques, and food processing methods. For example, reducing moisture levels during the storage of grains can help prevent fungal growth, thereby reducing the likelihood of ochratoxin contamination. In the wine industry, close monitoring of grape quality, along with proper storage conditions, is crucial in preventing fungal growth and minimizing the risk of ochratoxin contamination in the final product. Regulatory bodies around the world have established maximum allowable limits for ochratoxin levels in food, with specific limits varying by food type and geographical region.

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

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

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

10.7 MUSHROOM POISONING

Mushrooms are the fruiting bodies of fungi, which are part of a large group of organisms separate from plants, animals, and bacteria. They are the reproductive structures of certain types of fungi, and they grow above the ground to release spores, which are similar to seeds in plants. These spores help the fungi spread and reproduce. Mushrooms can be edible, toxic, or medicinal. Edible mushrooms, like button mushrooms and shiitake, are commonly used in cooking. Toxic mushrooms, such as the *Amanita* species, can be poisonous and sometimes lethal if consumed. Mushroom poisoning, also known as mushroom toxicity, occurs when mushrooms containing harmful toxins are consumed. This often happens during the foraging of edible mushrooms, where toxic varieties are mistaken for non-toxic ones due to their similar appearance. They are found all over the world, and although there are thousands of mushroom species, only around 100 are known to cause symptoms in humans when consumed. Of these, 15-20 species are potentially lethal, highlighting the risks associated with foraging wild mushrooms. The severity of mushroom poisoning can vary widely based on several factors, such as the geographic location where the mushroom is grown, the environmental conditions, the amount of toxin present, and the specific genetic characteristics of the mushroom. Since mushrooms can have significant variation in their appearance and toxic content, it's difficult to rely on simple rules to distinguish between edible and poisonous varieties.

In over 95% of mushroom poisoning cases, the cause is misidentification, often by inexperienced mushroom collectors. These individuals may mistakenly gather toxic mushrooms that closely resemble safe, edible species. The *Clitocybe dealbata*, also known as the sweating mushroom, can be easily confused with other edible mushrooms like the fairy ring champignon (*Marasmius oreadus*) or the sweetbread mushroom (*Clitopilus prunulus*). Similarly, the *Omphalotus olearius*, also called the Jack O' Lantern mushroom, is often mistaken for the edible chanterelle (*Cantharellus cibarius*). These mushrooms can look quite similar to their edible counterparts, which makes foraging dangerous without proper knowledge, as some of these toxic mushrooms can cause severe illness (Fig. 10.1). This highlights the dangers of foraging for wild mushrooms without proper knowledge or experience, as the consequences of consuming the wrong mushroom can be severe, ranging from gastrointestinal symptoms to liver and kidney failure, and in some cases, death. Mushroom toxins

include a range of harmful compounds, each with specific effects on the body. The most common types of toxins found in mushrooms are cyclopeptides (e.g., amatoxin), gyromitrins (e.g., monomethylhydrazine), orellanine, muscarine, psilocybin, coprine, nephrotoxins (e.g., norleucine), myotoxins, hemolytic toxins and GI irritants. Gastrointestinal (GI) irritants are the most commonly encountered mushroom toxins. Among these, amatoxins, gyromitrins, and orellanine are the toxins most often associated with fatal mushroom poisonings worldwide. Gyromitrins are known to be hepatotoxic, meaning they damage the liver, as well as having epileptogenic (seizure-inducing) properties. Orellanine and norleucine are nephrotoxic, causing damage to the kidneys. Meanwhile, muscarine, psilocybin, muscimol, and ibotenic acid are central nervous system (CNS) poisons, affecting brain function and behavior.



Clitocybe dealbata
(Sweating mushroom)



Marasmius oreadus
(Fairy ring champignon)



Omphalotus olearius
(Jack O'Lantern mushroom)



Cantharellus cibarius
(Chanterelle)

Fig. 10.1: Closely resembling edible and toxic mushroom species

10.8 PREVENTING FOODBORNE ILLNESS

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

- Keep packages of raw meat and poultry separate from other foods, particularly foods to be eaten without further cooking. Use plastic bags or other packaging to prevent raw juices from dripping on other foods or refrigerator surfaces.
- Buy products labeled “keep refrigerated” only if they are stored in a refrigerated case. Refrigerate promptly.
- Buy dated products before the label sell-by, use-by or pull-by date has expired.
- Wash hands (gloved or not) with soap and water for 20 seconds before preparing foods and after handling raw meat or poultry, touching animals etc.
- Rinse raw produce thoroughly under running tap water before eating.
- Scrub containers and utensils used in handling uncooked foods with hot, soapy water before using with ready-to-serve foods.
- Use separate cutting boards to help prevent contamination between raw and cooked foods.
- Serve cooked products on clean plates with clean utensils and clean hands.
- Keep hot foods hot (above 140 F) and cold foods cold (below 40 F).
- Refrigerate or freeze cooked leftovers in small, covered shallow containers (2 inches deep or less) within two hours after cooking. Leave airspace around containers to help ensure rapid, even cooling.
- Use cooked leftovers within 4 days. Don’t taste leftovers to determine safety.
- If reheating leftovers, cover and reheat to appropriate temperature before serving.
- Discard outdated, unsafe or possibly unsafe leftovers in the garbage disposal or in tightly wrapped packages.

10.9 SUM UP

In this unit, we explored various foodborne diseases in depth, providing a comprehensive overview of the bacteria, viruses, parasites, and fungi that cause them. The unit helped clarify the concept of food poisoning, distinguishing between food infection and food intoxication. It covered the organisms involved in foodborne illnesses, their symptoms, sources of contamination, and common foods linked to different illnesses. Further the unit also explored various poisoning effects of consumption of toxic

mushrooms. Additionally, the unit delved into the types of mycotoxins produced by fungi during their growth in food. It also outlined various methods for preventing foodborne illnesses in detail.

10.10 CHECK YOUR PROGRESS

1. Differentiate between food infection and food intoxication.

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2. List some bacteria that cause food borne illness.

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3. Write a short note on listeriosis.

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4. Explain zoonotic food borne illness.

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5. How can we prevent mycotoxins in food?

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6. Define mycotoxins.

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7. Explain the measures involved in preventing food borne illness.

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UNIT-XI PROCESSING CONTAMINANTS

Structure

- 11.1 Introduction
- 11.2 Concept of Processing Contaminants
- 11.3 Acrylamide
- 11.4 Furan
- 11.5 Nitrosamines
- 11.6 Polycyclic Aromatic Hydrocarbons (PAHs)
- 11.7 3-Monochloropropane-1,2-diol (3-MCPDE)
- 11.8 Oxyhalides
- 11.9 Sum Up
- 11.10 Check Your Progress

11.1 INTRODUCTION

This unit focuses on identifying and describing common processing contaminants in food. It explain how different food processing techniques, including deodorization, high-temperature cooking, and industrial refining, contribute to the formation of processing contaminants. We will learn about the potential health effects of consuming food contaminated with processing by-products. Additionally, the unit compares various detection techniques (e.g., GC-MS, HPLC) for identifying and quantifying processing contaminants in food. Additionally, it also explores strategies for reducing processing contaminants in food.

Objectives

Learning this unit will make you:

- define processing contaminants

- understand the types of processing contaminants
- evaluate the impact of food processing methods
- assess the health risks associated with processing contaminants
- explain the detection and quantification methods
- describe the strategies for reduction of processing contaminants
- discuss the methods of prevention of food illness

11.2 CONCEPT OF PROCESSING CONTAMINANTS

Food processing is the transformation of raw ingredients into consumable food products through various physical, chemical, or biological methods. It plays a crucial role in enhancing the shelf life, safety, and nutritional quality of food while meeting consumer demands for convenience and variety. Techniques like drying, freezing, canning, pasteurization, and fermentation are commonly used to preserve food and prevent spoilage caused by microorganisms. However, it is essential to balance processing techniques to retain the natural qualities of food while minimizing the use of artificial additives. As a vital link between agriculture and consumption, food processing significantly contributes to global food security and the reduction of post-harvest losses. However, processing contributes to development of some processing contaminants. They can form both during home cooking and in manufacturing processes, and in some cases, their presence at low levels may be unavoidable. While not all processing contaminants are harmful, some have been associated with potential health risks.

Processing contaminants are chemical substances that are unintentionally formed in food during various processing methods, such as cooking, frying, baking, or smoking. These contaminants are not present in the raw ingredients but are produced as a result of chemical reactions triggered by high temperatures, prolonged processing, or certain conditions during manufacturing. Common examples include acrylamide (formed during high-temperature cooking of starchy foods), polycyclic aromatic hydrocarbons (PAHs, found in grilled or smoked foods), and 3-monochloropropane-1,2-diol (3-MCPD, formed in refined oils and processed meats). While some processing contaminants occur naturally during cooking, their presence can pose health risks, including carcinogenic and toxic effects if consumed in large quantities over time. Regulatory bodies and food industries work to identify and minimize these contaminants through improved processing techniques, temperature controls, and alternative cooking methods. Consumer awareness about safe cooking practices, such as avoiding excessive charring or deep frying, can also help reduce exposure to these harmful substances.

11.3 ACRYLAMIDE

Acrylamide is a chemical compound that can form in certain foods during high-temperature cooking processes such as frying, baking, or roasting. It is primarily found in starchy foods like potato chips, French fries, bread, and baked goods when they are cooked at temperatures above 120°C (248°F). Acrylamide forms as a result of the Maillard reaction, which occurs between amino acids (such as asparagine) and sugars during heating. Acrylamide is typically absent in foods prepared using methods such as boiling or microwaving and is found in very low levels in animal-based food products like meat and fish. Currently, no global permissible limits have been established for acrylamide consumption in the diet. Factors such as variations in food composition, high cooking temperatures (above 120°C), and the presence of high levels of carbohydrates, free asparagine, reducing sugars, pH, water content, ammonium bicarbonate, and competing amino acids can influence the variation in acrylamide levels in foods. Usually, the darker the color of a food product, the higher is its acrylamide content. Acrylamide formation tends to increase significantly toward the end of the frying process.

- **Mechanism of Formation**

The primary pathway for acrylamide formation in foods is part of the Maillard reaction, which occurs when free amino acids (like asparagine) react with reducing sugars (mainly glucose and fructose) during high-temperature cooking methods such as baking or frying. This reaction is responsible for the desirable color, flavor, and aroma in cooked foods due to the interaction of carbohydrates, lipids, and proteins. Potatoes, for example, contain high levels of asparagines, which, when combined with glucose and fructose, leads to acrylamide formation. In potatoes, reducing sugars are the main limiting factor for acrylamide production, while in cereal products, the asparagine content (especially in the bran) plays a more significant role. Additionally, alternative routes for acrylamide formation have been suggested. In lipid-rich foods, acrylamide can form through reactions involving acrolein and ammonia when asparagine is absent. Acrolein and acrylic acid are byproducts of lipid breakdown (triglycerides) under high temperatures and may also contribute to acrylamide formation.

- **Detection and Quantification**

Acrylamide and its metabolites in foods are typically quantified using GC–MS, either with or without derivatization. The use of GC–MS allows for efficient sample isolation from the matrix, improving the detection of acrylamide in food. A common method for derivatization involves bromination of acrylamide before analysis. Coupling GC with MS enhances the detection range and

reduces interference. Liquid chromatography-tandem mass spectrometry (LC–MS) is also used to determine acrylamide and its metabolites, with LC being particularly effective for separating water-soluble and non-volatile compounds. Samples are generally homogenized in water, standards are added, and fat extraction is performed using hexane and cyclohexane. Additional reagents help purify the sample by removing protein residues. A final purification step is carried out through evaporation and solid-phase extraction (SPE) cartridges, resulting in acrylamide collection. High-performance liquid chromatography (HPLC) offers advantages like high sensitivity and efficiency for acrylamide quantification. Capillary electrophoresis (CE) is another promising method, requiring smaller sample sizes and providing fast analysis with efficient separation, making it effective for detecting trace components like acrylamide. While CE shows potential for non-volatile compounds and can serve as an alternative to gas chromatography, reproducible quantification requires optimization of gas pressure, liquid composition, flow rate, and capillary temperature. Despite the time required for sample preparation and analysis, GC–MS and LC–MS remain the most sensitive methods for acrylamide quantification in food.

- **Health Hazards**

While acrylamide is not intentionally added to foods, its presence has raised concerns because it has been classified as a potential human carcinogen by health organizations. However, dietary exposure is typically much lower than levels associated with these risks. The primary concern regarding the potential health effects of acrylamide in food is its carcinogenicity and genotoxicity, specifically its ability to damage DNA. Acrylamide has been shown to cause tumors in laboratory rats, and although extensive studies have been conducted to determine whether it causes cancer in humans, there is no conclusive evidence linking it to human cancer. Nonetheless, the International Agency for Research on Cancer (IARC) has classified acrylamide as a probable human carcinogen. Additionally, acrylamide has been found to be neurotoxic in humans and may interfere with reproductive processes. Various international organizations, including the European Food Safety Authority, the Food and Agriculture Organization (FAO) of the United Nations, and the World Health Organization (WHO), have assessed the health risks associated with acrylamide in food. Based on its toxicity, these bodies have all concluded that efforts should be made to reduce acrylamide levels in food.

- **Mitigation Strategies**

Efforts to reduce acrylamide include adopting cooking methods such as boiling or steaming, using lower cooking temperatures, and choosing ingredients with reduced levels of precursors like

asparagine. Public awareness about safe cooking practices, such as avoiding excessive browning or burning of foods can also help at domestic level. To minimize acrylamide formation in food, it is important to select crop cultivars with low levels of reducing sugars while considering seasonal and regional variations, especially for high-temperature processes like frying and baking. Potato tubers should not be stored below 6°C, as this increases reducing sugar levels; an ideal storage temperature of around 8°C should be maintained. However, many retailers and consumers are unaware of these guidelines. Raising awareness through mass media campaigns and efforts by food safety authorities is crucial to ensure proper practices. Blanching potatoes in water before frying at controlled temperature and time can effectively reduce acrylamide formation in potato products. In bakery and cereal products, using additives like amino acids, asparaginase enzymes, cations, and antioxidants has been reported to lower acrylamide levels. Additionally, using flour with low asparagine content can help decrease acrylamide in baked goods. Introducing steam into conventional baking systems is another effective way to reduce acrylamide content in bakery products. These strategies collectively promote safer food production and consumption.

11.4 FURAN

Furans are a class of organic compounds that are formed in food during cooking or processing, particularly at high temperatures. They are cyclic compounds containing a five-membered ring of four carbon atoms and one oxygen atom. Furans can be formed through the Maillard reaction, a complex process involving sugars and amino acids that occurs during the heating of food, especially when food is fried, roasted, or baked. It is found in coffee, canned foods, baked foods etc.

- **Mechanism of Formation**

Furan formation in food can arise from several sources. These include thermal degradation or Maillard reaction of reducing sugars, either alone or in combination with amino acids, thermal breakdown of certain amino acids, thermal oxidation of ascorbic acid, oxidation of polyunsaturated fatty acids, and degradation of carotenoids. The main source of furan in food, however, is the thermal degradation of carbohydrates like glucose, lactose, and fructose. Reducing hexoses participate in Maillard reactions when combined with amino acids, leading to the formation of reactive intermediates such as 1-deoxy- and 3-deoxyosones. The 1-deoxyosone undergoes alpha-dicarbonyl cleavage to produce aldotetrose. Aldotetrose can also be formed through retro-aldol cleavage in the absence of amino acids, though this occurs to a lesser extent. All these aldotetrose derivatives can easily be

converted into furan. Pentose sugars, such as ribose, can also generate furan, particularly in the presence of amino acids. Similar to hexoses, pentoses can be converted into 3-deoxyosone derivatives through a reaction with amino acids or by dehydration at the C-3 hydroxyl group. The resulting intermediate can undergo alpha-dicarbonyl cleavage to produce 2-deoxyaldotetrose, which is a direct precursor to furan.

- **Detection and Quantification**

Due to its high volatility, furan can be analyzed using headspace gas chromatography-mass spectrometry (HS-GC-MS). A straightforward headspace method for furan determination in food has been developed by the US FDA. For semi-solid or solid foods, five-gram test portions are diluted with water, spiked with an internal standard (d4-furan), and sealed in headspace vials. Similarly, ten-gram test portions of liquid foods are fortified with d4-furan and sealed in headspace vials. Automated headspace sampling, followed by gas chromatography/mass spectrometry (GC/MS) analysis, is used to detect both furan and d4-furan in selected-ion monitoring (SIM) mode. Furan is quantified using a standard additions curve. The headspace method has the advantage of not requiring sample purification, making it simpler and more efficient. Additionally, it can be automated, allowing for high sample throughput, which is beneficial for large-scale analyses.

- **Health Hazards**

Furan is rapidly and extensively absorbed through the intestine and lungs and can pass through biological membranes, allowing it to enter various organs. Studies have shown that furan is carcinogenic in rats and mice, with a dose-dependent increase in hepatocellular adenomas and carcinomas in both sexes. Furan is found to induce cancer in experimental animals and International Agency for Research on Cancer (IARC) has declared it as probable human carcinogen. Furans, particularly 2,5-dimethylfuran, are of concern due to their potential toxicity. Some furans, including 2,3,4,5-tetrachlorodibenzo-p-dioxin (TCDD) and others, are known to have carcinogenic properties, though the concentrations found in food are typically very low. The International Agency for Research on Cancer (IARC) has identified some furan derivatives as possible human carcinogens based on animal studies. However, preliminary exposure data suggest that the levels of furan found in foods are much lower than those that would cause harmful effects. Despite the potential health risks, the actual exposure to harmful levels of furans through diet is generally considered to be low, and regulatory bodies like the European Food Safety Authority (EFSA) and the U.S. Food and Drug Administration (FDA) continue to monitor levels in food.

- **Mitigation Strategies**

Mitigating furan levels in food involves several strategies aimed at reducing its formation during cooking and processing. Some of the key approaches include reducing cooking temperatures and avoiding overcooking or charring can help limit furan formation. Lowering the temperature during processes like roasting, frying, and baking has been found to reduce furan production. Antioxidants, such as vitamin C and polyphenols, may inhibit the formation of furan by interfering with the oxidative processes that contribute to its production. Reducing the levels of certain precursors, such as reducing sugars and amino acids, can also help mitigate furan formation. Adjusting the formulation of processed foods, such as using less sugar or different types of fat, may reduce the furan levels in the final product. Adjusting parameters like time, temperature, and moisture content during food processing can reduce furan formation. For example, controlling the humidity and time during roasting can help lower furan levels in roasted products. These strategies, especially when applied together, can help minimize the formation of furan in food, reducing potential health risks. However, it is still recommended to reduce the intake of highly processed and heated foods to minimize exposure to furans and other potentially harmful compounds.

11.5 NITROSAMINES

Nitrite is a food additive used in meat and meat products as preservative and colour fixative. Nitrites react with break down product of protein and produce nitrosamines. Nitrosamines are a group of chemical compounds that are typically formed by the reaction of nitrites (often used as preservatives in processed meats) with amines, which are organic compounds found in proteins and other food components. Nitrosamines are of significant concern because many of them are considered carcinogenic (cancer-causing), especially when consumed in large quantities over time. These compounds can form during food processing, such as the curing of meats, or during cooking, particularly when food is fried or grilled at high temperatures. They can be found in tobacco smoke and in some alcoholic beverages. They are also formed during processing like in bacon and beer. Subsequent research has demonstrated that various processing and packaging methods can also introduce trace amounts of these carcinogens into foods. These methods include drying foods using air heated by direct flame, migration of contaminants from food contact surfaces, and the direct addition of contaminants during processing. Common examples of nitrosamines include N-Nitrosodimethylamine (NDMA), N-Nitrosodiethylamine (NDEA), N-Nitrosopyrrolidine (NPYR) etc.

Nitrosamines are classified into two groups: volatile and non-volatile nitrosamines. Several factors influence the concentration of these compounds, including the type of cooking method and temperature, the residual amount of nitrite, the concentration of nitrosamine precursors, and the presence of nitrosamine inhibitors. Certain compounds, such as α -tocopherol (vitamin E) and ascorbic acid (vitamin C), act as inhibitors of nitrosamine formation during food production. Additionally, storage conditions can also impact the levels of nitrosamines in foods.

- **Detection and Quantification**

Various extraction methods have been developed to determine nitrosamines, including microwave-assisted extraction, superheated water extraction, and supercritical fluid extraction, which often require specialized equipment. Among the different methods used to detect nitrosamines in food samples, thermal energy analyzers (TEA), ultraviolet detectors, nitric oxide analyzers (NOA), and gas chromatography/flame-ionization detection (GC/FID) are the most commonly employed. When compared to TEA, GC/FID, and ultraviolet detectors, these techniques are particularly effective for identifying and quantifying nitrosamines in food.

- **Health Hazards**

Most of the nitrosamines are mutagenic and can become carcinogens under certain conditions. These compounds can induce gene mutations in both bacteria, potentially affecting the microbiome, and mammalian cells. This can lead to the formation of DNA adducts, which may disrupt normal cellular functions. Furthermore, such mutations could potentially interfere with gut-brain and gut-cardiac physiology, leading to broader health implications. The contamination of food by nitrosamines poses a significant public health risk, contributing to the increasing prevalence of stomach and colon cancer. To mitigate this risk, strategies such as reducing the use of nitrites in food, along with improved quality control measures, should be implemented. These efforts would benefit from collaborative input from both the food industry and regulatory agencies to ensure safer food production practices.

11.6 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a diverse group of organic compounds made up of two or more fused aromatic rings. They are primarily generated through the incomplete combustion or pyrolysis of organic materials, as well as during various industrial processes. PAHs typically exist as

complex mixtures containing hundreds of compounds. Human exposure to PAHs occurs through multiple pathways. For non-smokers, the primary route of exposure is through food consumption, while for smokers, smoking significantly contributes to their exposure. Food contamination with PAHs can result from environmental pollution, industrial food processing, or certain home cooking methods. They are considered both as environmental and process contaminants. The European Commission has identified four key polycyclic aromatic hydrocarbons (PAHs), referred to as PAH4, as major indicators of contamination in foods (Fig. 11.1). These include benz[a]anthracene (BaA), chrysene (Chr), benzo[b]fluoranthene (BbF), and benzo[a]pyrene (BaP).

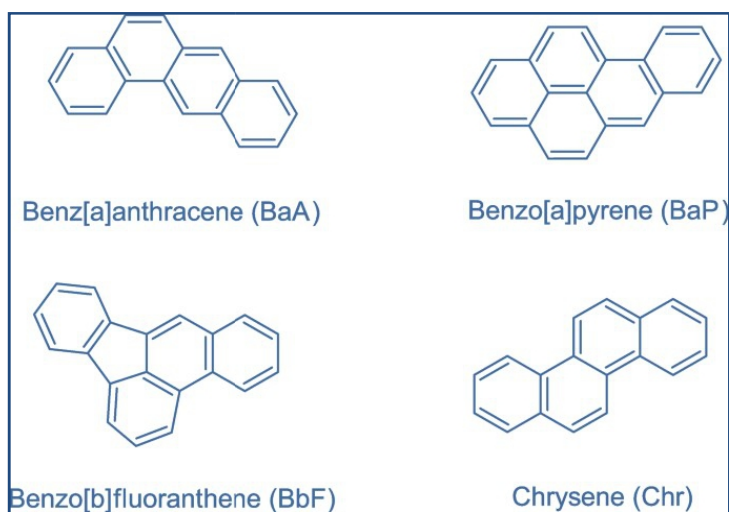


Fig. 11.1: Structure of major polycyclic aromatic hydrocarbons (PAHs)

(Adapted from Lobsiger et al., 2023)

- **Mechanism of Formation**

PAHs can contaminate food during industrial processes such as smoking, heating, and drying, where combustion products come into direct contact with the food. Contamination of cereals and vegetable oils often occurs during processes like direct fire drying, where combustion products interact with grains, oil seeds, or oils. Certain home cooking methods, such as grilling, roasting, and smoking, also contribute to the formation of PAHs. Elevated levels of PAHs have been found in charcoal-grilled or barbecued foods, especially fatty meats cooked under prolonged or intense conditions. Smoked foods, such as fish, and seafood from polluted waters are additional sources of PAHs. Coffee has also

been reported to contain PAHs, possibly due to contamination during the drying process or formation during roasting.

- **Detection and Quantification**

The method chosen for extracting PAHs from food samples largely depends on the characteristics of the food matrix. For solid food samples, such as meat, fish, and their products, saponification followed by liquid-liquid extraction or organic solvent extraction are commonly used. In contrast, liquid-liquid extraction is often employed for liquid samples, like vegetable oils. Automated extraction techniques, such as pressurized liquid extraction (PLE) and supercritical fluid extraction (SFE), are also utilized for solid food matrices, though less frequently. To isolate PAHs from interfering substances within the matrix, purification methods like column chromatography, solid-phase extraction (SPE), and gel permeation chromatography (GPC) are typically employed. Currently, the primary analytical techniques for determining PAHs in food are high-performance liquid chromatography (HPLC) coupled with a fluorescence detector (FLD) and gas chromatography-mass spectrometry (GC-MS). Both methods provide sufficient sensitivity to detect PAH concentrations commonly found in food.

- **Health Hazards**

The absorption of PAHs is enhanced by their lipophilic nature and increased solubility in fats, allowing them to bind to cell membranes. This interaction causes structural changes in the membranes, disrupting normal cellular functions. Among PAHs, benzo[a]pyrene (BaP) is the most readily solubilized by lipids. It can associate with lipid transport molecules, such as chylomicrons and other lipoproteins, enabling it to infiltrate systems involved in lipid absorption and distribution. This process promotes the bioaccumulation of BaP in tissues and organs actively engaged in lipid metabolism, such as the liver and small intestine. Short-term exposure to PAHs can cause skin and eye irritation, nausea, vomiting, and inflammation. Long-term exposure is linked to more severe health issues, including cancers of the skin, lungs, bladder, and gastrointestinal tract, as well as kidney and liver damage, cataracts, genetic mutations, cell damage, and increased risk of cardiopulmonary-related mortality. Data from experiments show them to be mutagenic, genotoxic and carcinogenic. PAHs can induce chromosomal mutations, disrupt fusion and junction processes, and potentially cause chromosomal breaks, leading to instability in the genetic material of affected cells. If DNA repair mechanisms fail, the genotoxic effects of PAHs can permanently alter the cell's DNA during the initiation phase of transcription, leading to a pre-neoplastic cell, potentially setting the stage for tumor development.

- **Mitigation Strategies**

Alternative cooking methods can help minimize the formation of PAHs in prepared foods. These include cooking at lower temperatures, grilling the lean portions of meat to reduce fat drippings, avoiding direct contact between food and flames during barbecuing, and opting for electric or gas broilers instead of charcoal grills. Selecting appropriate combustible materials in traditional smoking methods is crucial to minimizing PAH contamination. Additionally, the distance and position of the food relative to the smoking source play a significant role in reducing the level of contamination.

11.7 3-MONOCHLOROPROPANE-1,2-DIOL (3-MCPDE)

3-Monochloropropane-1,2-diol (3-MCPD) is a common contaminant in processed oils, primarily forming during the deodorization step of the edible oil refining process. It has been detected in various food products, including infant formula, margarine, bread, and soy sauce. Exposure to 3-MCPD may lead to health concerns, such as kidney and testicular damage. During industrial refining, 3-MCPD esters (3-MCPDE) and glycidyl esters (GE) can form in edible oils when they are heated to high temperatures to eliminate undesirable tastes, colors, or odors. The highest concentrations of these compounds are typically found in refined palm oil and palm olein oil. However, 3-MCPDE and GE can also be present in other refined vegetable oils, such as safflower, coconut, sunflower, and soybean oils, as well as in refined marine oils like fish oils.

Various factors influence the formation of 3-MCPD during heating processes, including temperature, duration, glycerin content, and the presence of salt ingredients. These factors can significantly affect the levels of 3-MCPD produced. Recent studies have highlighted the complex chemical changes that cooking oils undergo at high temperatures, such as starch gelatinization and protein denaturation, which may result in the formation of 3-MCPD in fried foods. Additionally, processes designed to improve the overall quality of oils can inadvertently increase 3-MCPD production. For example, refining processes, particularly deodorization, which involves steam distillation at high temperatures, can promote 3-MCPD formation. During deodorization, heat-induced degradation of triglycerides into free fatty acids, production of trans-isomers, and loss of sterols and tocopherols may contribute to this process. The presence of precursors like monoacylglycerols, diacylglycerols, lecithin, and chlorinated compounds can also play a role in the formation of 3-MCPD.

Exposure to 3-MCPD has been shown to cause harmful effects both in vivo and in vitro. The kidneys and male reproductive system are the primary target organs affected by 3-MCPD. In terms of carcinogenicity, these contaminants are classified as Group 2B, meaning they are possibly carcinogenic to humans. In addition to its potential carcinogenic effects, 3-MCPD has been linked to toxicity in the lungs and heart, as well as immunosuppressive effects, male reproductive toxicity, and neurotoxicity.

Detection of 3-MCPD and its esters in food and oils is typically carried out using advanced analytical techniques. Gas chromatography-mass spectrometry (GC-MS) is one of the most commonly employed methods due to its high sensitivity and ability to separate and identify specific compounds. Additionally, more recent approaches include liquid chromatography-tandem mass spectrometry (LC-MS/MS) and gas chromatography with an electron capture detector (GC-ECD), which provides enhanced sensitivity and precision in quantifying low levels of 3-MCPD and its esters. These methods are crucial for monitoring contamination levels and ensuring food safety.

11.8 OXYHALIDES

Oxyhalides in food refer to a group of chemical compounds that contain halogens (such as chlorine, bromine, or iodine) bonded to oxygen. These compounds can be found as contaminants in food, often as a result of industrial processes, contamination from environmental sources, or the use of certain food additives. Some oxyhalides, such as chlorates and perchlorates, may be present due to the use of chlorinated water or disinfectants during food processing. These compounds can pose potential health risks when consumed in high amounts, as they may interfere with the thyroid function or have other toxic effects. Therefore, monitoring and controlling oxyhalide levels in food is important for food safety.

Oxyhalides are among the key by-products formed in bottled water during disinfection processes like ozonation. Chlorite, chlorate, and bromate are recognized as oxyhalides, and disinfection by-products (DBPs) are typically generated at concentrations around the mg/l level during water purification. During the disinfection process, the presence of organic materials or naturally occurring halides in the water source, which may not be fully removed during treatment, can lead to the formation of undesirable DBPs. These include chlorite, bromate, and trihalomethanes, which result from reactions between disinfectants and the organic and inorganic materials in the original water, which can pose potential health risks to humans. The International Agency for Research on Cancer

(IARC) has not classified chlorite and chlorate due to insufficient toxicological data. However, the World Health Organization (WHO) has recommended provisional guideline values of about 0.7 mg/l for both chlorate and chlorite concentrations in filtered water, based on a tolerable daily intake of 30 mg/kg body weight. In contrast, potassium bromate has been classified as a Group 2B carcinogen, meaning it is possibly carcinogenic to humans. Recent studies suggest that even bromate concentrations below 1 µg/l may pose significant cancer risks over a lifetime.

11.9 SUM UP

In this unit, we were able to recognize common processing contaminants in food, such as PAHs, 3-MCPD, and glycidyl esters, and understand the conditions under which they form. The unit helped clarify understanding of how various food processing techniques, such as deodorization, frying, and refining, contribute to the production of harmful by-products. Students will be proficient in explaining and applying analytical methods, such as GC-MS and HPLC, to detect and quantify processing contaminants in food samples. Further the unit also suggested effective strategies for minimizing processing contaminants, including cooking practices, ingredient selection, and alternative food processing technologies.. Additionally, the unit delved into the explaining and applying analytical methods, such as GC-MS and HPLC, to detect and quantify processing contaminants in food samples.

11.10 CHECK YOUR PROGRESS

- 1. Define processing contaminants.

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- 2. List some common processing contaminants in food.

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3. Write a short note on oxyhalides.

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4. What is acrylamide? Explain the mechanism of acrylamide formation.

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5. How can we prevent development of furans in food?

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6. Explain health hazards associated with polycyclic aromatic hydrocarbons (PAHs).

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7. Explain importance of 3-Monochloropropane-1,2-diol in food industry.

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UNIT-XII FOOD LABELLING

Structure

- 12.1 Introduction
- 12.2 Definition
- 12.3 Need for Labelling
- 12.4 Key Terminology
- 12.5 Specific Labelling Requirements
- 12.6 Labelling for Special Foods
- 12.7 Food Fraud and Food Authentication
- 12.8 Sum Up
- 12.9 Check Your Progress

12.1 INTRODUCTION

Food labeling, food fraud, and food authenticity are critical components of modern food safety and quality control systems. Labels serve as a communication tool between producers and consumers, offering essential information about the food product's composition, nutritional content, origin, and safety standards. Food fraud, which includes practices such as mislabeling, adulteration, and substitution, can undermine public health and trust in the food supply. At the same time, food authenticity ensuring that products are genuine and meet the expected standards protects consumers from health risks and ensures fair trade practices. This chapter will explore the significance of food labeling, the regulatory requirements involved, the impact of food fraud, and methods to verify food authenticity.

Objectives

Learning this unit will make you:

- define food labelling
- understand the role and importance of food labelling
- explain the terms related to labelling
- identify specific labelling requirements
- understand the concept of food fraud
- explain the concept of food authenticity
- list advanced evaluation methods for verifying food authenticity

12.2 DEFINITION

Food labelling refers to the information provided on food packaging that informs consumers about the product's ingredients, nutritional content, and other essential details. It is a legal requirement in many countries to ensure transparency and help consumers make informed choices about the food they buy and consume. Food labeling ensures consumer safety by providing critical information about allergens or harmful ingredients. It helps consumers make nutritional choices in line with their dietary needs or preferences, supports regulatory compliance and builds trust between manufacturers and consumers and ensures transparency in marketing. Food labels play a vital role in promoting food safety and consumer awareness, empowering people to make healthier and safer choices.

12.3 NEED FOR LABELLING

The need for food labelling arises from its critical role in ensuring consumer safety, promoting informed decision-making, and fostering transparency in the food industry. Food labelling provides essential information about the product, including its name, ingredients, nutritional value, allergens, expiry date, and storage instructions. This information helps consumers make healthier choices based on their dietary needs, preferences, or restrictions, such as avoiding allergens or selecting low-sodium or high-protein foods. Moreover, labelling serves as a safeguard against foodborne illnesses by guiding proper storage and usage. It also supports regulatory compliance by ensuring that food manufacturers disclose accurate details about their products, thereby minimizing the risk of misleading claims. Additionally, labels act as a tool for traceability, enabling the identification of product batches in case of recalls or safety concerns. Beyond health and safety, labelling aids in consumer trust by providing transparency about the origin, quality, and ethical standards of food production, such as organic certification or fair trade practices. In a competitive market, clear and accurate labelling also assists in

marketing while helping consumers differentiate between products, ultimately ensuring a safer and more informed purchasing experience.

12.4 KEY TERMINOLOGY

Some terms are essential for understanding food labels and ensuring compliance with food safety regulations. Here are some key terms related to food labelling and their definitions:

- **Label**

Any tag, brand, mark, pictorial or other descriptive matter that is written, printed, stenciled, marked, embossed, impressed, or attached to a container of food.

- **Labelling**

Includes any written, printed, or graphic matter present on the label, accompanying the food, or displayed near the food, which is intended to provide information or promote the sale or disposal of the food product.

- **Food**

Any substance, whether processed, partially processed, or unprocessed, that is intended for human consumption. This includes beverages, chewing gum, and any substances used as ingredients in the preparation of food. It excludes cosmetics, medicines, and substances like tobacco.

- **Prepackaged**

Refers to food that is fully or partially enclosed in packaging in such a way that the contents cannot be altered without opening or changing the packaging. Prepackaged foods are prepared and packed before being offered for sale and are usually labeled with relevant information like ingredients and expiry dates.

- **Nutritional Information**

Details about the nutrient content of a food product, including energy, protein, fat, carbohydrates, vitamins, minerals, and sometimes dietary fiber or added sugars.

- **Ingredient List**

A comprehensive list of all ingredients used in the food product, typically arranged in descending order of their weight or volume contribution.

- **Ingredient**

Any substance, including food additives, used in the manufacture or preparation of a food product and present in the final product, even if in altered form. Ingredients must be listed on the label in descending order of their weight or volume in the product.

- **Allergen Declaration**

A mandatory disclosure of potential allergens present in the food, such as nuts, dairy, gluten, soy, or shellfish, to prevent allergic reactions.

- **Date of Manufacture**

The date on which the food product is produced or processed into its final form as described on the label.

- **Date of Packaging**

The date on which the food product is placed in its immediate container or packaging, ready for sale to the consumer.

- **Best Before Date**

Indicates the date until which the food product is expected to retain its optimal quality and safety under proper storage conditions.

- **Use by Date**

Specifies the final date by which the food must be consumed for safety reasons, as consuming it after this date may pose health risks.

- **Country of Origin**

Details the country where the food product was grown, processed, or manufactured.

- **Additives**

Substances added to food products to enhance flavor, appearance, shelf life, or nutritional value, such as preservatives, colorants, or flavor enhancers.

- **Health Claims**

It is a statement on the label suggesting a relationship between the food product and health benefits, such as "lowers cholesterol" or "rich in antioxidants," which must comply with regulatory standards.

- **Serving Size**

A standardized amount of the food product recommended for consumption, often used to calculate the nutritional information per serving.

- **Barcode**

It is a machine-readable code that helps track the product for inventory management, traceability, and pricing.

- **Storage Instructions**

These are guidelines provided on the label to ensure the product remains safe and maintains its quality, such as "keep refrigerated" or "store in a cool, dry place."

- **Lot**

A specific quantity of food products that are produced, processed, or packaged under similar conditions during a particular time period.

- **Batch Number/Lot Number**

It is a unique identifier for a specific batch of food products, used for traceability and recall purposes.

12.5 SPECIFIC LABELLING REQUIREMENTS

The Food Safety and Standards Authority of India (FSSAI) mandates specific labelling requirements for prepackaged foods to ensure consumer safety and informed choices. These requirements are outlined in the Food Safety and Standards (Labelling and Display) Regulations, 2020. The key mandatory labelling elements include:

1. Name of the Food: The product's common or descriptive name must be clearly stated to indicate its true nature.

(a) If a food product has an essential composition defined under the Food Safety and Standards Regulations established under the Act, the specified name that identifies the product must be used.

(b) If no such name is defined, the food product should be labeled with either a common or usual name or a description that accurately reflects its true nature.

(c) Additionally, a "coined," "fanciful," "brand," or "trade name" may be used, provided it complies with the Food Safety and Standards (Advertising and Claims) Regulation, 2018.

2. List of Ingredients: All ingredients should be listed in descending order of their weight or volume at the time of manufacture. This includes additives and must clearly specify any allergens present in the product. For ingredients belonging to specific classes, the class titles may be used such as edible oils and fats, starches, spices and condiments, leavening agents etc. Added water must be declared in the list of ingredients, unless it is a component of another ingredient, such as brine, syrup, or broth, where the water is an integral part of that ingredient.

3. Nutritional Information: A detailed nutritional facts table per 100g or 100ml or per serving, including energy value, protein, fat, carbohydrates (with sugar), and any other nutrient for which a nutrition or health claim is made. This information helps consumers understand the nutritional value of the product.

4. Declaration Regarding Veg or Non-Veg: A symbol indicating whether the product is vegetarian (a green circle inside a green square) or non-vegetarian (a brown circle inside a brown square) must be displayed prominently. This assists consumers in making dietary choices aligned with their preferences.

5. **Declaration of Food Additives:** If the product contains permitted food additives, their functional class and specific names or International Numbering System (INS) numbers must be declared. This ensures transparency about the substances used in the product.
6. **Name and Address of the Manufacturer:** The name and complete address of the manufacturer, packer, or importer must be provided. In the case of imported food, the name and address of the importer is required. This information is crucial for traceability and consumer inquiries.
7. **Net Quantity:** The net weight, volume, or number of the contents must be declared accurately. This allows consumers to understand the exact quantity of the product they are purchasing.
8. **Lot/Code/Batch Identification:** A code number or lot number or batch number is required for identification and traceability purposes. This is essential for managing product recalls or addressing quality issues.
9. **Date of Manufacture or Packing:** The date on which the product was manufactured or packed should be mentioned. This helps in assessing the product's freshness.
10. **Best Before and Use by Date:** The date until which the product is best suited for consumption must be stated. If the product has a shelf life of less than seven days, the 'Use By' date is required. This information guides consumers on the product's safety and quality.
11. **Country of Origin for Imported Food:** For imported products, the country of origin must be declared. If the food undergoes processing in a second country that changes its nature, the country where the processing occurred should be declared as the country of origin. This provides transparency about the product's sourcing.
12. **Instructions for Use:** If applicable, instructions on how to use or prepare the product should be provided to ensure it is consumed safely and effectively.

These labelling requirements are designed to provide consumers with essential information about prepackaged foods, enabling them to make informed choices and ensuring transparency in the food industry. For detailed regulations, refer to the Food Safety and Standards (Labelling and Display) Regulations, 2020.

12.6 LABELLING FOR SPECIAL FOODS

- **Allergen Labelling**

Food producers are required to clearly highlight allergens in the ingredient list on labels for pre-packaged foods. They can use methods such as keeping the text in bold, italics, or underlining the text

or changing the text color for emphasis. There are 14 specific allergens or allergenic substances that must be highlighted, as they can cause allergies or intolerances:

1. Cereals containing gluten (e.g., wheat, barley, rye, oats).
2. Crustaceans (e.g., prawns, crabs, lobster, crayfish).
3. Peanuts.
4. Eggs.
5. Fish.
6. Nuts (e.g., almonds, hazelnuts, walnuts, cashews, pecans, pistachios, brazil nuts, macadamia nuts).
7. Soybeans.
8. Milk.
9. Celery and celeriac.
10. Mustard.
11. Sesame seeds.
12. Lupin.
13. Molluscs (e.g., clams, mussels, oysters, squid, whelks).
14. Sulphur dioxide/sulphites (used as a preservative in some dried fruits) when present at levels above 10 mg/kg or 10 mg/l.

- **Irradiated Foods**

The labelling of irradiated foods is regulated to ensure transparency and inform consumers that the product has undergone ionizing radiation treatment. All foods that have been treated with ionizing radiation must carry a clear declaration stating, "*Treated with ionizing radiation*" or "*Irradiated*." This declaration should appear on the main label of the product, ensuring visibility to the consumer. A distinctive international symbol known as the *Radura* must be displayed on the label (Fig. 12.1).



Fig. 12.1: Labelling symbol of Irradiated Food

- **Genetically Modified Foods**

Labelling of genetically modified (GM) foods is mandated to ensure transparency and help consumers make informed choices. Foods or ingredients that have been genetically modified (GM) must carry a clear and conspicuous statement, such as *"This product contains genetically modified organisms (GMOs)"* or *"This product is genetically modified."* GM labelling is required if the GM content in the product exceeds a specified threshold (e.g., 1% or more of the total ingredients in many countries, including India). Products labelled as "Non-GMO" or "GMO-Free" must be backed by certification or evidence to avoid misleading consumers.

- **Organic Food**

The Food Safety and Standards Authority of India (FSSAI) has specific guidelines for the labeling of organic food, as outlined in the Food Safety and Standards (Organic Foods) Regulations, 2017. These regulations aim to ensure that organic food products meet the standards and provide transparency to consumers. Organic food must have certification details based on either National Programme for Organic Production (NPOP) or Participatory Guarantee System (PGS-India) or any other system approved by FSSAI. The label should include the statement: **"Organic Food"** prominently to indicate the product is organically produced. All organic food products must display the Jaivik Bharat logo, which signifies compliance with organic standards (Fig. 12.2). Misleading information, such as terms like "100% organic" for uncertified products, is prohibited.



Fig. 12.2: Labelling symbol of Organic Food

- **Fortified food**

The Food Safety and Standards Authority of India (FSSAI) has established guidelines for labeling fortified foods under the Food Safety and Standards (Fortification of Foods) Regulations, 2018. All fortified food products must display the Fortified Food Logo which indicates that the food is fortified with essential micronutrients (Fig. 12.3). The label must include the statement “Fortified with [name of nutrient(s)]” eg. "Fortified with Iron." Some commonly fortified staple foods are:

- Wheat flour (atta) – Fortified with iron, folic acid, and vitamin B12.
- Rice – Fortified with iron, folic acid, and vitamin B12.
- Edible oil – Fortified with vitamin A and vitamin D.
- Milk – Fortified with vitamin A and vitamin D.
- Salt – Fortified with iodine and iron.



Fig. 12.3: Labelling symbol of Fortified Food

12.7 FOOD FRAUD AND FOOD AUTHENTICITY

Food fraud involves the intentional alteration, misrepresentation, mislabeling, substitution, or tampering of a food product at any stage of the farm-to-table supply chain. It can occur in raw materials, ingredients, finished products, or even in the packaging. It often compromises the safety, quality, and authenticity of food, posing significant health risks to consumers. Common examples of food fraud include:

- Providing false or misleading information on packaging, especially about origin, ingredients, or certifications like selling non-organic food as "organic".

- Imitating well-known brands or food products to deceive consumers like producing fake versions of branded chocolates, coffee, or alcoholic beverages or selling counterfeit certified organic or GI-tagged products.
- Using non-approved additives, colors, or chemicals to improve the appearance or shelf life of a product eg. using malachite green to make fish look fresher or adding non-permitted synthetic dyes to turmeric or sweets.

Some famous food fraud scandals include Horsemeat Scandal in 2013 in Europe where horsemeat was found in beef products sold in supermarkets, misleading consumers. Another case occurred in China where baby formula was adulterated with melamine, a toxic chemical, leading to illnesses and deaths. Similarly in Italy, olive oil marketed as extra virgin was found to be diluted with low-quality oils. In India, fruits such as mangoes, were treated with calcium carbide (a toxic chemical) for artificial ripening. Food fraud impacts more than just financial losses and reputational damage; it poses significant risks to public health. Contaminated or mislabeled food products can lead to severe consequences, including allergic reactions, foodborne illnesses, and long-term health issues. Consuming inauthentic foods compromises both safety and well-being.

Food authenticity is a significant concern for both the food industry and consumers due to various factors, including legal compliance, adherence to religious dietary practices, economic considerations (ensuring the right products at fair prices), and the guarantee of consistent, well-defined quality through the use of appropriate, non-harmful ingredients. Food is deemed authentic or genuine when its composition and contents align with its original state and match the information provided on the label. Authentic products are free from adulteration, particularly in terms of their composition, nature, varietal purity, geographical origin, and manufacturing process. Food authenticity ensures not only safety and quality but also provides financial benefits to both producers and consumers. By authenticating their products, producers can protect their brand and reputation, while consumers gain confidence in the quality and reliability of the products they purchase.

Evaluation methods for food authenticity involve a range of advanced techniques to detect adulteration, mislabeling, and fraud. Chemical analysis, such as chromatography and spectroscopy, identifies the composition and contaminants in food. DNA-based methods, like PCR and DNA barcoding, verify species or plant origin, while isotopic analysis determines geographical authenticity through stable isotope ratio analysis. Spectral imaging techniques, including hyperspectral imaging

and Raman spectroscopy, help analyze food quality and detect impurities. Additionally, physical property analysis, such as microscopy and refractometry, evaluates texture, structure, or sugar content. Elemental analysis, using techniques like inductively coupled plasma mass spectrometry, detects trace elements or heavy metals, ensuring the authenticity and safety of food products.

Preventing food fraud requires a multi-faceted approach involving strict regulatory enforcement, advanced food testing techniques, and robust traceability systems. Agencies like FSSAI must implement stringent compliance standards and conduct regular inspections to deter fraudulent practices. Advanced technologies such as DNA analysis, isotope testing, and blockchain-based supply chain tracking can help verify authenticity and trace the origin of food products. Additionally, raising consumer awareness about recognizing authentic products and certifications plays a crucial role in reducing the prevalence of food fraud.

12.8 SUM UP

In this unit, learners were able to understand the importance of accurate and transparent food labeling in ensuring consumer trust and compliance with regulatory standards. We gained knowledge of specific labeling requirements, such as FSSAI guidelines for organic and fortified foods, and the role of labels in communicating critical information about nutritional content, allergens, and certifications. Learners also developed an awareness of food fraud, its various forms, and its impact on public health, industry reputation, and economic integrity. Additionally, they understood the concept of food authenticity, its significance in maintaining quality and ethical practices, and the advanced evaluation methods used to verify authenticity and detect fraud. This unit equipped students with the skills to identify and address labeling issues, assess food safety, and promote consumer confidence in the food supply chain.

12.9 CHECK YOUR PROGRESS

1. Define:

a) Food Labelling

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b) Food Fraud

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c) Food authenticity

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d) Fortified food

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2. Explain the specific labeling requirements of a food product.

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3. Write a short note on need for food labelling.

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4. Explain the following terms:

a) Ingredient

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b) Batch/Lot Number

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c) Additives

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d) Health Claims

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5. List allergens that should be specified in food labeling.

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6. Write a short note on methods for evaluation of food authenticity.

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SUGGESTED ONLINE LINKS

- http://www.who.int/foodsafety/publications/fs_management/en/surface_decon.pdf
- <http://www.foodsafety.gov/poisoning/causes/bacteriaviruses/norovirus/>
- <http://www.foodsafetywatch.org/e-books/biological-hazards-in-food/>
- <https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2008.724>
- <https://www.fssai.gov.in/>
- <https://www.fda.gov/>
- <https://www.fao.org/fao-who-codexalimentarius/en/>
- <https://www.fao.org/4/y1579e/y1579e03.htm>
- <https://www.iso.org/standard/62085.html>

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