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# FST 501

## CEREALS AND TUBERS TECHNOLOGY

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- Course code: FST 501
- Course title: Cereals and Tubers Technology
- Course credit load: 3

# Series 1: Cereals and Tubers Fundamentals

**Series outline**

- **1.1 Botanical Characteristics**
    - 1.1.1 Classification of cereals
    - 1.1.2 Classification of tubers
    - 1.1.3 Morphological features
- **1.2 Composition and Properties**
    - 1.2.1 Nutritional composition
    - 1.2.2 Physical properties
    - 1.2.3 Functional properties
- **1.3 Comparative Analysis**
    - 1.3.1 Similarities in structure and use
    - 1.3.2 Differences in composition and processing
    - 1.3.3 Implications for food technology
- **1.4 Role in Food Systems**
    - 1.4.1 Staple food significance
    - 1.4.2 Industrial applications
    - 1.4.3 Socio-economic importance

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**Introduction**

Cereals and tubers form the backbone of diets across the world, serving as staple foods that provide energy, nutrients, and cultural identity. From maize and rice to cassava and yams, these crops are not only vital for daily sustenance but also for industrial applications in food processing and product development. As learners in food science and technology, it is essential to grasp the fundamental characteristics of cereals and tubers, since they underpin the more advanced topics you will encounter later in this course.

The aim of this Series is to equip you with a clear understanding of the botanical features, composition, and properties of cereals and tubers, while also enabling you to analyse their similarities, differences, and roles within food systems.

We shall commence this Series by examining the **botanical characteristics** of cereals and tubers, focusing on their classification and morphological features. Next, we will explore their **composition and properties**, including nutritional, physical, and functional aspects. Following that, we will engage in a **comparative analysis** to highlight both similarities and differences between cereals and tubers, as well as their implications for food technology. Finally, we will wrap up by considering their **role in food systems**, emphasising their importance as staple foods, their industrial applications, and their socio-economic significance.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 1.1** define the botanical characteristics of cereals and tubers, including their classification and morphological features,
- **SLO 1.2** explain the nutritional, physical, and functional properties of cereals and tubers,
- **SLO 1.3** analyse the similarities and differences between cereals and tubers in terms of composition and processing,
- **SLO 1.4** evaluate the role of cereals and tubers in food systems, including their staple significance, industrial applications, and socio-economic importance.

## 1.1 Botanical Characteristics

### 1.1.1 Classification of cereals

Cereals are **grasses cultivated for their edible grains**, which are technically seeds enclosed in a fruit wall. The most common cereals include maize, rice, wheat, sorghum, and millet. Each cereal belongs to the family **Poaceae**, also known as the grass family. Within this family, cereals are classified based on their grain structure, growth habit, and climatic adaptation. For instance, rice thrives in waterlogged conditions, while sorghum and millet are drought-tolerant crops suited to semi-arid regions.

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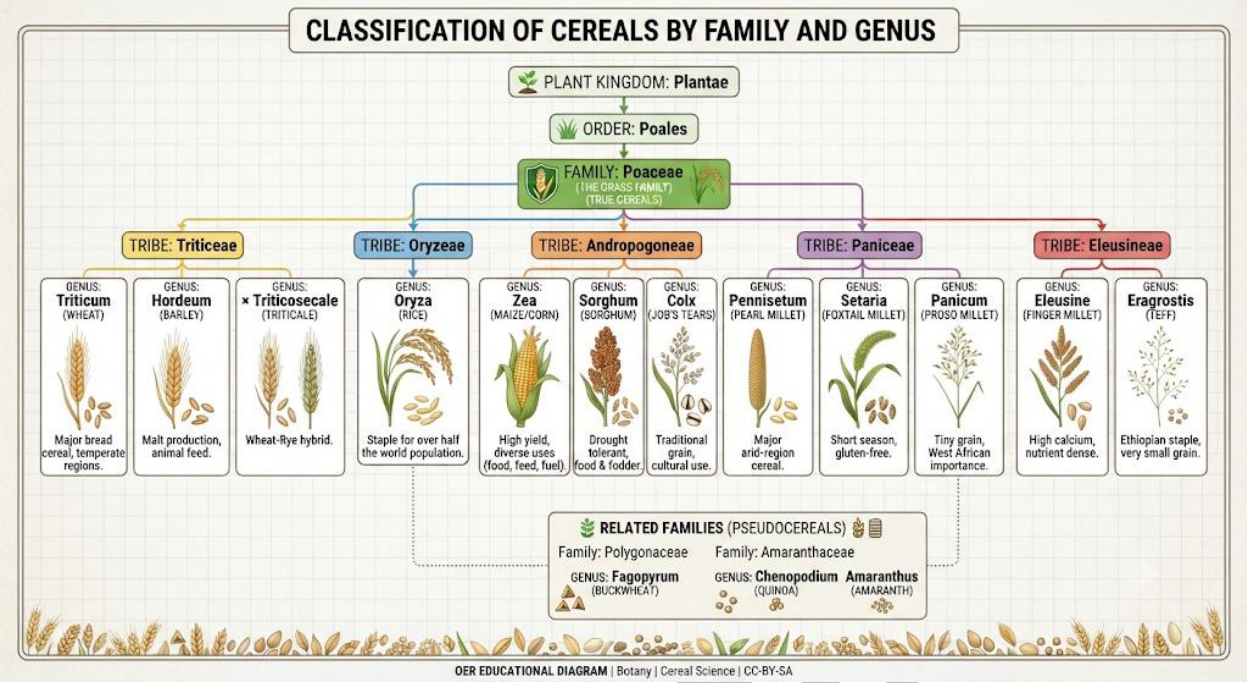


Diagram showing classification of major cereals by family and genus Caption: Figure 1.1 Classification of cereals

Fill in the blank: Cereals belong to the botanical family _____.

### 1.1.2 Classification of tubers

Tubers are **enlarged underground storage organs** of plants, usually formed from stems or roots. They serve as reservoirs of carbohydrates, mainly starch, and are consumed widely as staple foods. Examples include cassava, yam, and cocoyam. Botanically, tubers are classified into **stem tubers** (such as yam) and **root tubers** (such as cassava). Cocoyam, although often grouped with yams, belongs to the family **Araceae** and is considered a corm rather than a true tuber.

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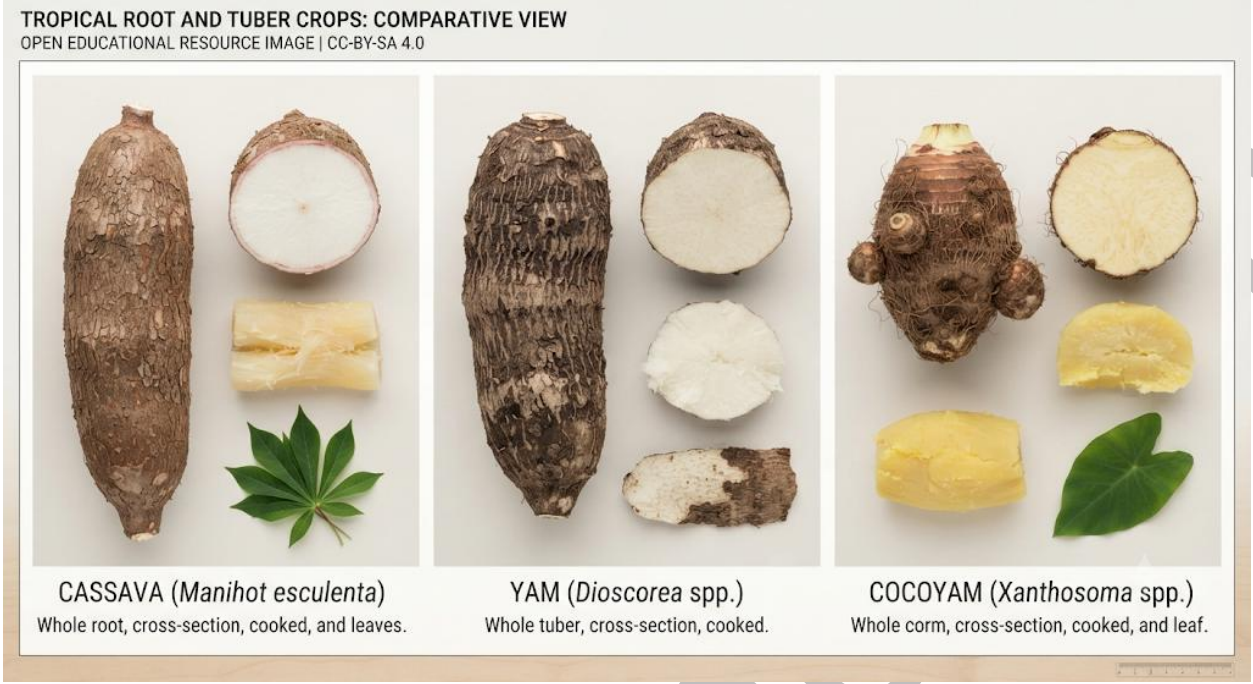


Image showing examples of cassava, yam, and cocoyam Caption: Plate 1.1 Common tubers used as staple foods

Fill in the blank: Cassava is classified as a _____ tuber.

**1.1.3 Morphological features**

The **morphology** of cereals and tubers refers to their external and internal structures. Cereals typically consist of a grain with three main parts: the **bran** (outer covering rich in fibre), the **endosperm** (starchy portion providing energy), and the **germ** (embryo rich in vitamins and oils). Tubers, on the other hand, are characterised by their enlarged storage tissues, which contain starch granules. Yams display nodes and internodes on their tuber surface, while cassava roots are cylindrical with rough bark-like skin. Cocoyams are smaller, with a corm structure and fibrous roots.

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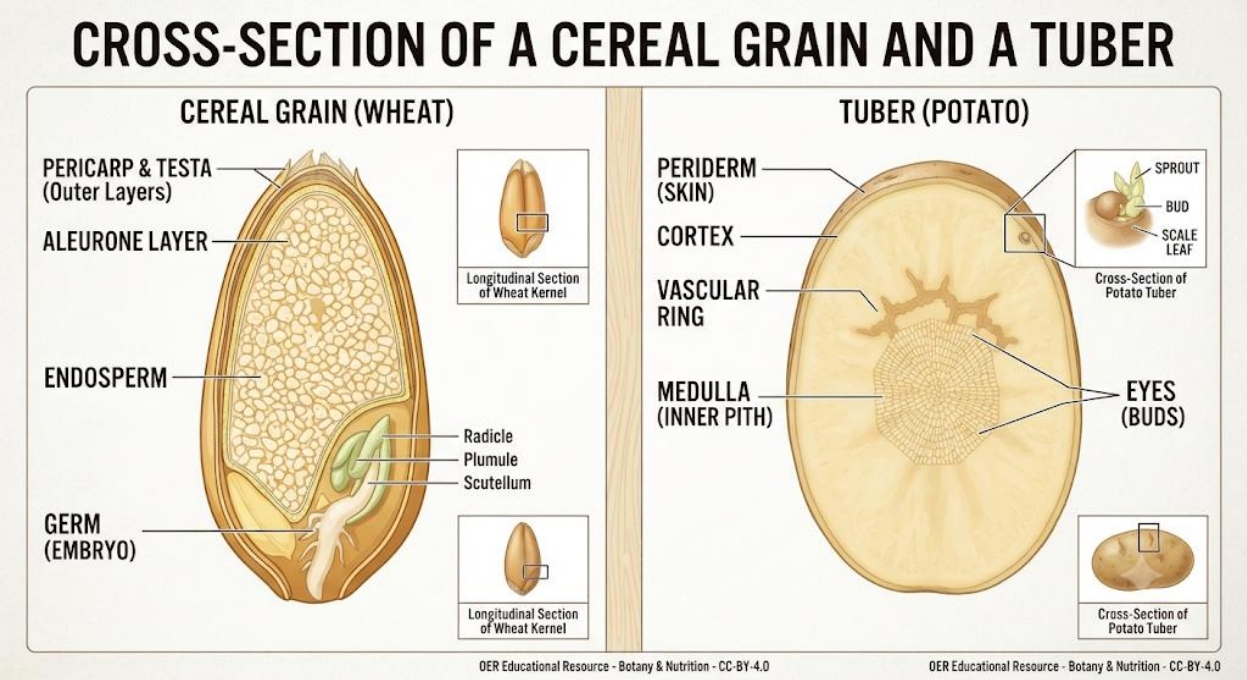


Cross-sectional diagram of a cereal grain and a tuber Caption: Figure 1.2 Comparative morphology of a cereal grain and a tuber

Fill in the blank: The starchy portion of a cereal grain is called the _____.

**Pilot questions 1.1**

1. Which botanical family do cereals belong to?
2. Differentiate between stem tubers and root tubers with examples.
3. Identify the three main parts of a cereal grain.
4. Which tuber is considered a corm rather than a true tuber?
5. State one morphological difference between yam and cassava.

### 1.2 Composition and Properties

#### 1.2.1 Nutritional composition

Cereals and tubers are valued primarily for their **nutritional composition**, which refers to the types and amounts of nutrients they contain. Cereals are rich in **carbohydrates**, mainly in the form of starch, and they also provide proteins, vitamins, and minerals. However, the protein quality of cereals is often limited due to low levels of essential amino acids such as lysine. Tubers, on the other hand, are predominantly sources of starch, with varying amounts of fibre, vitamins, and minerals. For example, cassava is high in carbohydrates but low in protein, while yams contain more dietary fibre and micronutrients.

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**NUTRITIONAL COMPOSITION OF SELECTED STAPLE CROPS** (PER 100g EDIBLE PORTION)

| FOOD CROP (SOURCE) | CARBOHYDRATE (g) | PROTEIN (g) | FIBRE (g) | VITAMINS & KEY MICRONUTRIENTS (mg/100g or as specified) |
|---|---|---|---|---|
| MAIZE (CEREAL) | 74.3 | 9.4 | 7.3 | Vitamin C: 6.8mg<br>Vitamin A: 205µg<br>Folate: 19µg |
| RICE (CEREAL, Brown, Raw) | 76.2 | 7.5 | 2.8 | Vitamin B1: 0.4mg<br>Vitamin B3: 5.1mg<br>Vitamin B6: 0.5mg |
| CASSAVA (TUBER) | 38.1 | 1.4 | 1.8 | Vitamin C: 20.6mg<br>Folate: 27µg<br>Potassium: 271mg |
| YAM (TUBER) | 27.9 | 1.5 | 4.1 | Vitamin C: 17.1mg<br>Vitamin B6: 0.2mg<br>Potassium: 816mg |

**NOTES:** Source: USDA FoodData Central (Illustrative Data, values may vary by variety)
**OER** Educational Resource - CC-BY-4.0 - Plant Illustration by AI

Comparison of nutritional composition of selected cereals and tubers Caption: Table 1.1 Nutritional composition of cereals and tubers

Fill in the blank: The amino acid that is often limited in cereals is _____.

**1.2.2 Physical properties**

The **physical properties** of cereals and tubers describe their measurable characteristics such as size, shape, colour, and texture. Cereals are typically small, dry grains with hard outer coverings, while tubers are larger, fleshy storage organs. The physical properties influence handling, storage, and processing. For instance, the hardness of wheat grains determines their suitability for bread-making, while the moisture content of cassava roots affects their shelf life.

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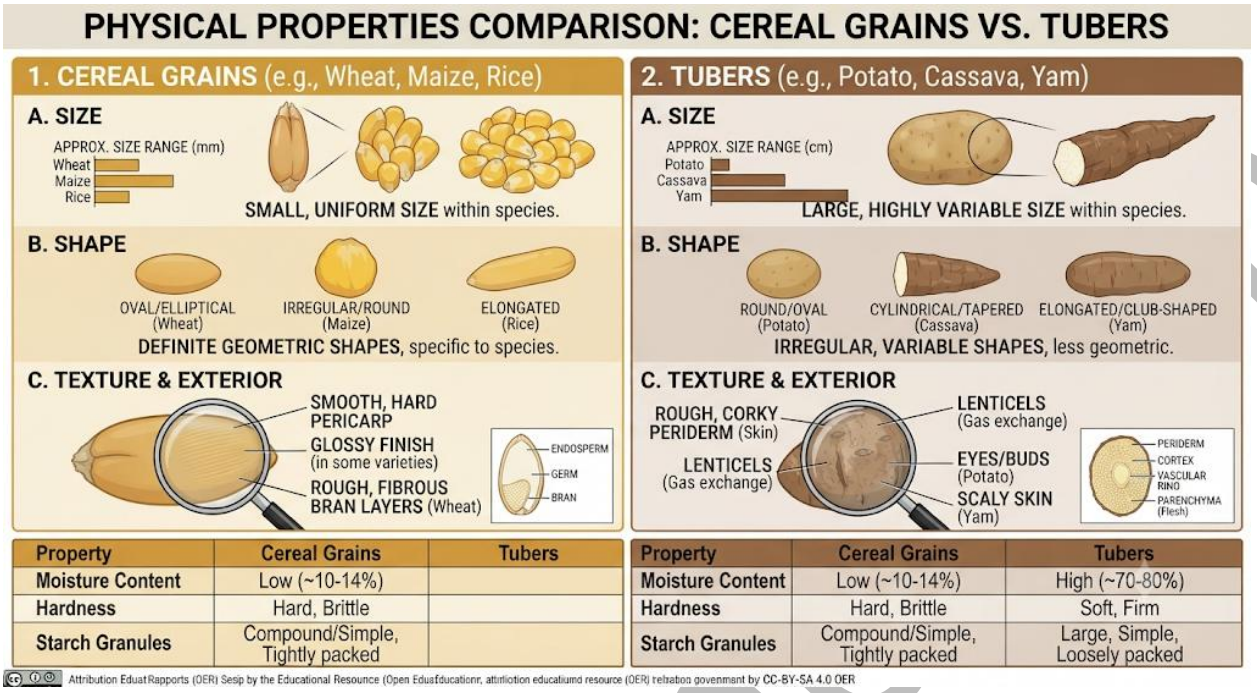


Diagram showing physical differences between cereal grains and tubers Caption: Figure 1.3 Physical properties of cereals and tubers

Fill in the blank: The hardness of _____ grains is important for bread-making.

### 1.2.3 Functional properties

The **functional properties** of cereals and tubers refer to how their components behave during food preparation and processing. Cereals provide **gluten**, a protein complex in wheat that gives dough elasticity and allows bread to rise. Tubers contribute **starch**, which acts as a thickening agent in soups and sauces. Functional properties also include water absorption, gelatinisation, and pasting behaviour. These properties determine the suitability of cereals and tubers for different food products.

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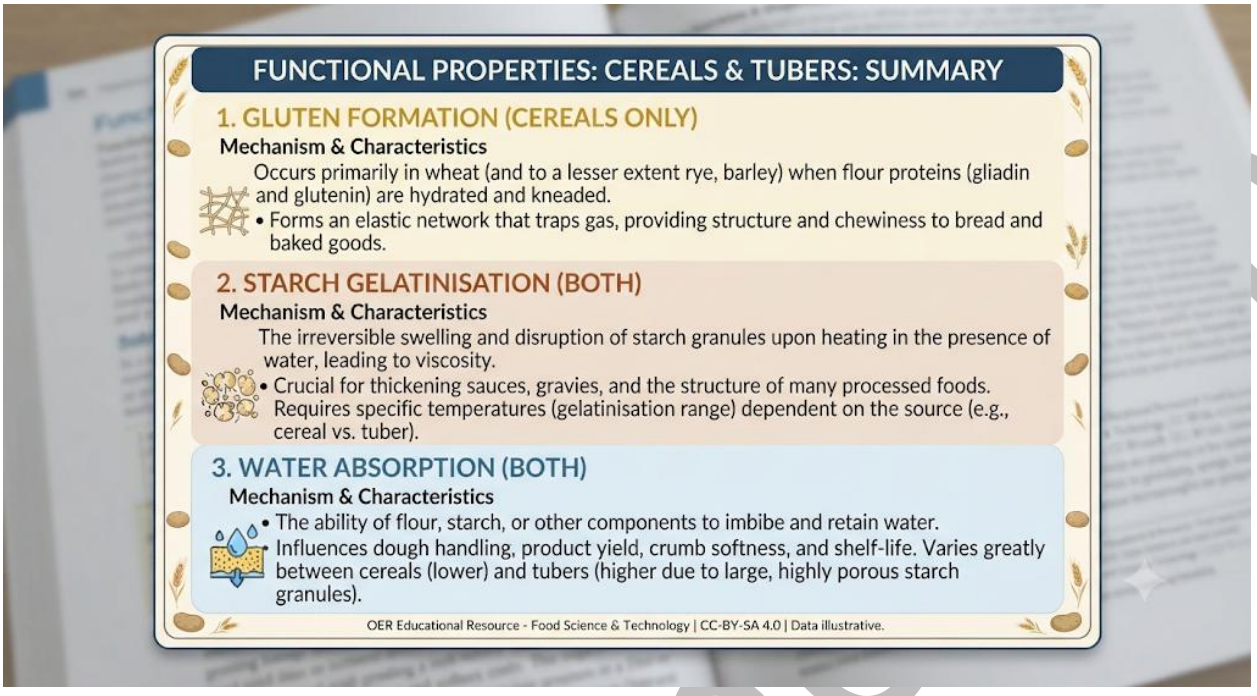

Box 1.1 Selected functional properties of cereals and tubers

Fill in the blank: The protein complex in wheat that gives dough elasticity is called _____.

**Pilot questions 1.2**

1. Which nutrient is the primary component of both cereals and tubers?
2. Name one amino acid that is deficient in cereals.
3. How does the moisture content of cassava affect its shelf life?
4. What protein complex in wheat contributes to bread-making?
5. State one functional property of tuber starch.

### 1.3 Comparative Analysis

#### 1.3.1 Similarities in structure and use

Cereals and tubers share several **similarities** in their role as staple foods. Both are rich in **carbohydrates**, which serve as the primary source of energy in human diets. They also provide dietary fibre, vitamins, and minerals, although in varying proportions. Structurally, cereals and tubers both contain storage tissues that accumulate starch granules, which are later utilised during germination or sprouting. In terms of use, both are versatile ingredients in food preparation, forming the basis of traditional dishes across cultures.

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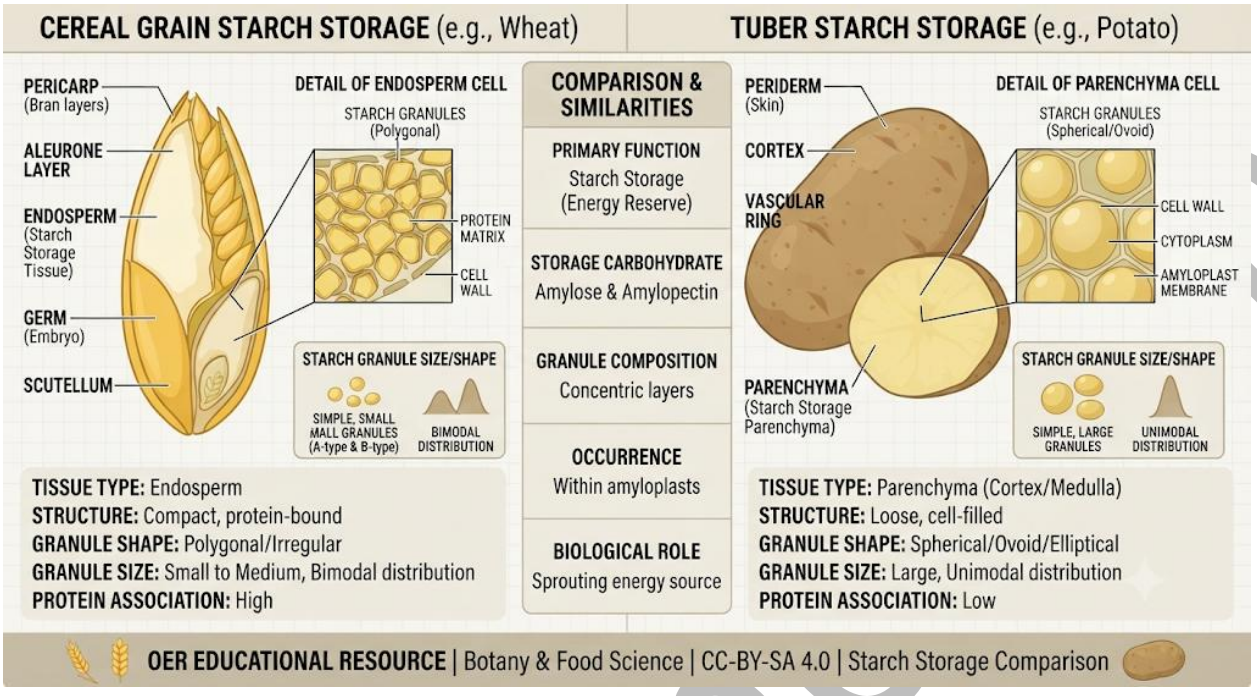


Diagram showing similarities in starch storage between cereals and tubers Caption: Figure 1.4 Similarities in starch storage structures

Fill in the blank: Both cereals and tubers are rich in _____, which is the main source of dietary energy.

### 1.3.2 Differences in composition and processing

Despite their similarities, cereals and tubers differ significantly in **composition** and **processing requirements**. Cereals generally contain higher protein levels compared to tubers, although the protein quality is limited. Tubers, however, are almost entirely carbohydrate-based, with lower protein content. Processing methods also differ: cereals are typically milled into flour, while tubers are peeled, grated, fermented, or boiled before consumption. For example, wheat is milled into flour for bread-making, whereas cassava must undergo detoxification to remove cyanogenic compounds before being processed into gari or flour.

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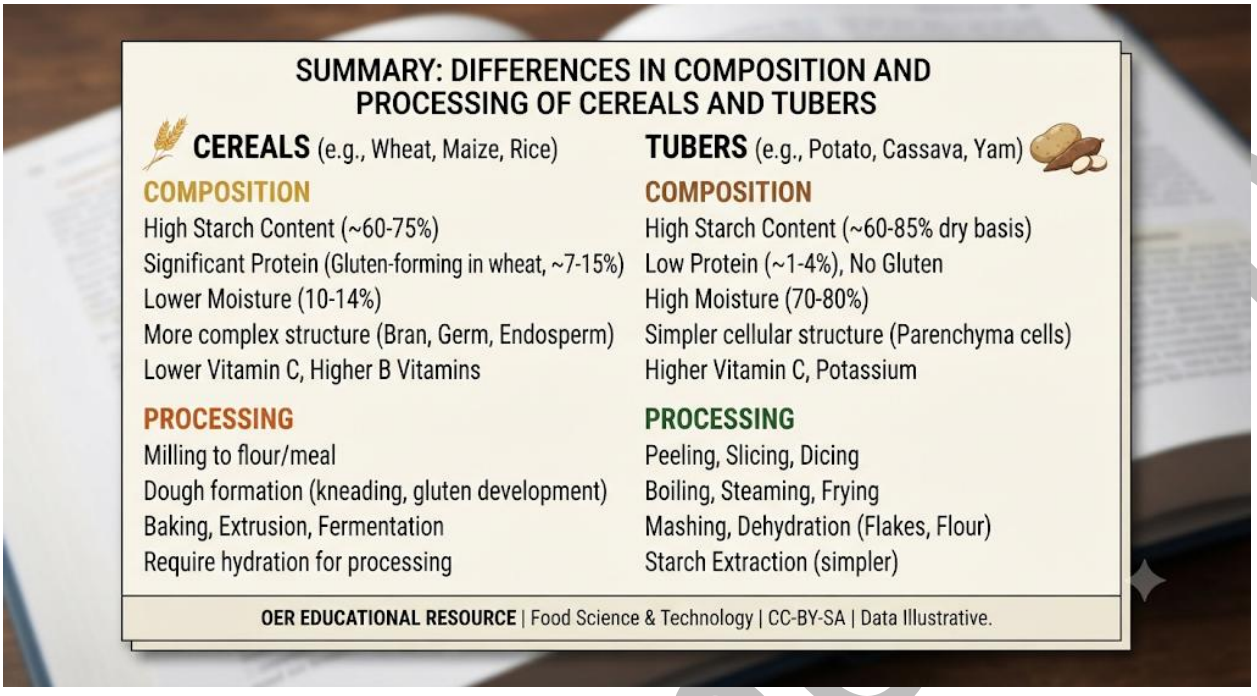

Box 1.2 Key differences between cereals and tubers

Fill in the blank: Cassava must be processed to remove _____ compounds before consumption.

### 1.3.3 Implications for food technology

The differences and similarities between cereals and tubers have important **implications for food technology**. Cereals, with their gluten-forming proteins, are ideal for bakery products, while tubers, with their high starch content, are better suited for thickening agents, snack production, and composite flour formulations. Understanding these implications allows food technologists to design products that combine the strengths of both groups. For instance, composite flours made from wheat and cassava can reduce reliance on imported wheat while maintaining desirable baking qualities.

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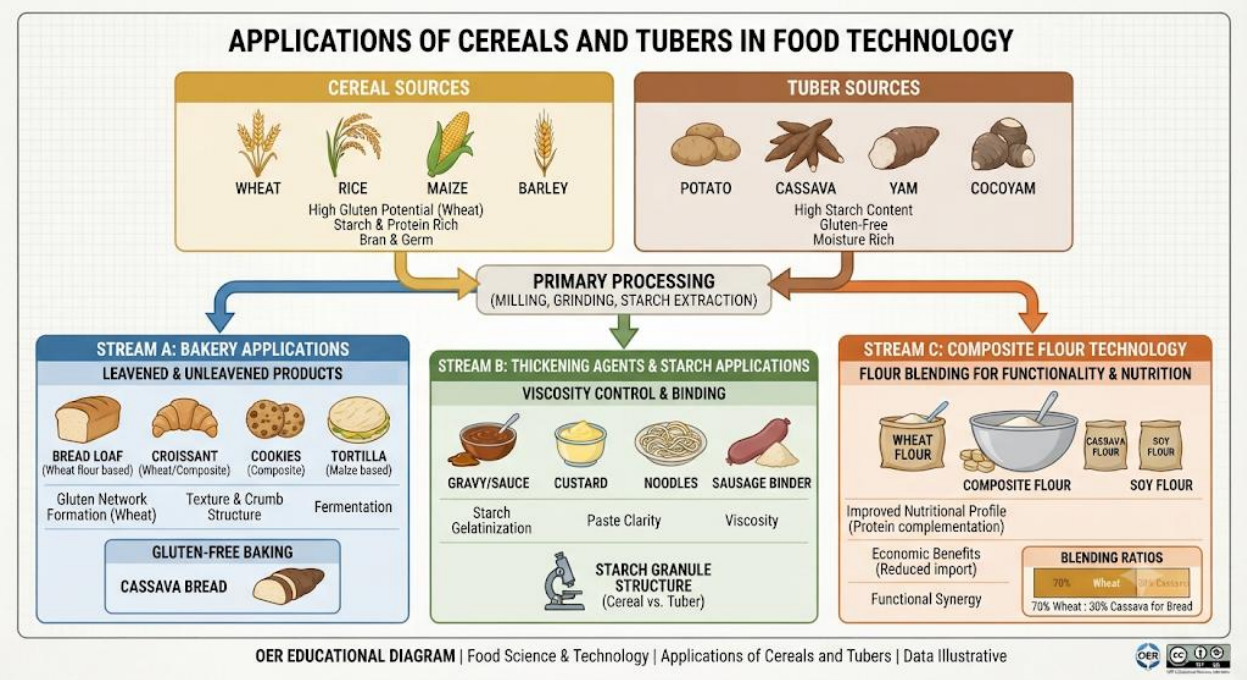


Diagram showing applications of cereals and tubers in food technology Caption: Figure 1.5 Applications of cereals and tubers in food technology

Fill in the blank: Composite flours often combine wheat with _____ to reduce reliance on imported wheat.

**Pilot questions 1.3**

1. What is the main nutrient similarity between cereals and tubers?
2. Which group generally contains more protein, cereals or tubers?
3. Why must cassava undergo detoxification before processing?
4. What property of cereals makes them suitable for bakery products?
5. Give one example of how cereals and tubers can be combined in food technology.

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**1.4 Role in Food Systems**

**1.4.1 Staple food significance**

Cereals and tubers hold immense importance as **staple foods**, meaning they are consumed regularly and in large quantities to meet daily energy needs. In many parts of Africa, Asia, and Latin America, cereals such as rice, maize, and sorghum, alongside tubers like cassava and yam, form the foundation of traditional diets. Their affordability, availability, and adaptability to different cooking methods make them indispensable in ensuring food security.

Image showing staple dishes made from cereals and tubers (e.g., rice, maize porridge, yam, cassava gari) Caption: Plate 1.2 Staple foods derived from cereals and tubers

Fill in the blank: Foods that are consumed regularly and in large quantities to meet daily energy needs are called _____ foods.

### 1.4.2 Industrial applications

Beyond household consumption, cereals and tubers have wide-ranging **industrial applications**. Cereals are processed into flour for bakery products, malt for brewing, and starch for food additives. Tubers are used to produce starch, flour, chips, and even bioethanol. For example, cassava starch is widely employed in the food industry as a thickener, while maize starch is used in

confectionery and paper manufacturing. These applications highlight their versatility and economic value.

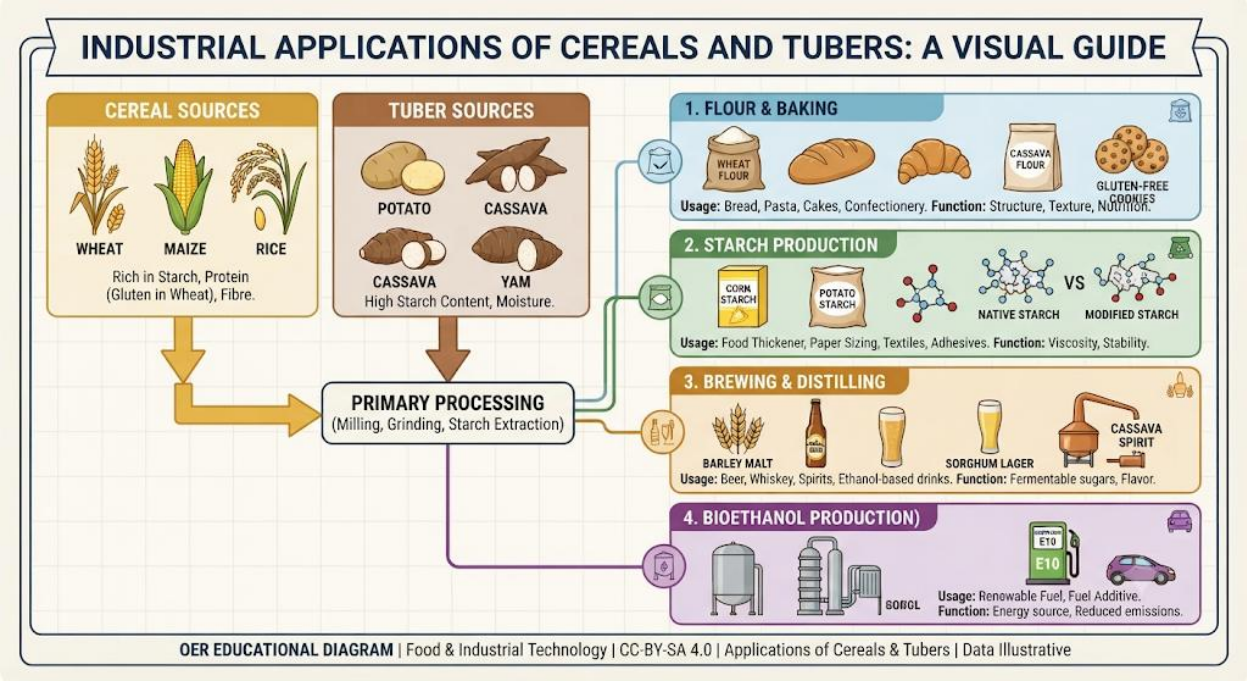


Diagram showing industrial uses of cereals and tubers Caption: Figure 1.6 Industrial applications of cereals and tubers

Fill in the blank: Cassava starch is widely used in the _____ industry as a thickener.

### 1.4.3 Socio-economic importance

The cultivation and utilisation of cereals and tubers carry significant **socio-economic importance**, particularly in developing regions. They provide employment opportunities for farmers, processors, and traders, while also contributing to national economies through exports. Moreover, they play a role in cultural identity, with traditional dishes often centred around these crops. For instance, yam festivals in West Africa celebrate the harvest season, reinforcing the cultural and economic value of tubers.

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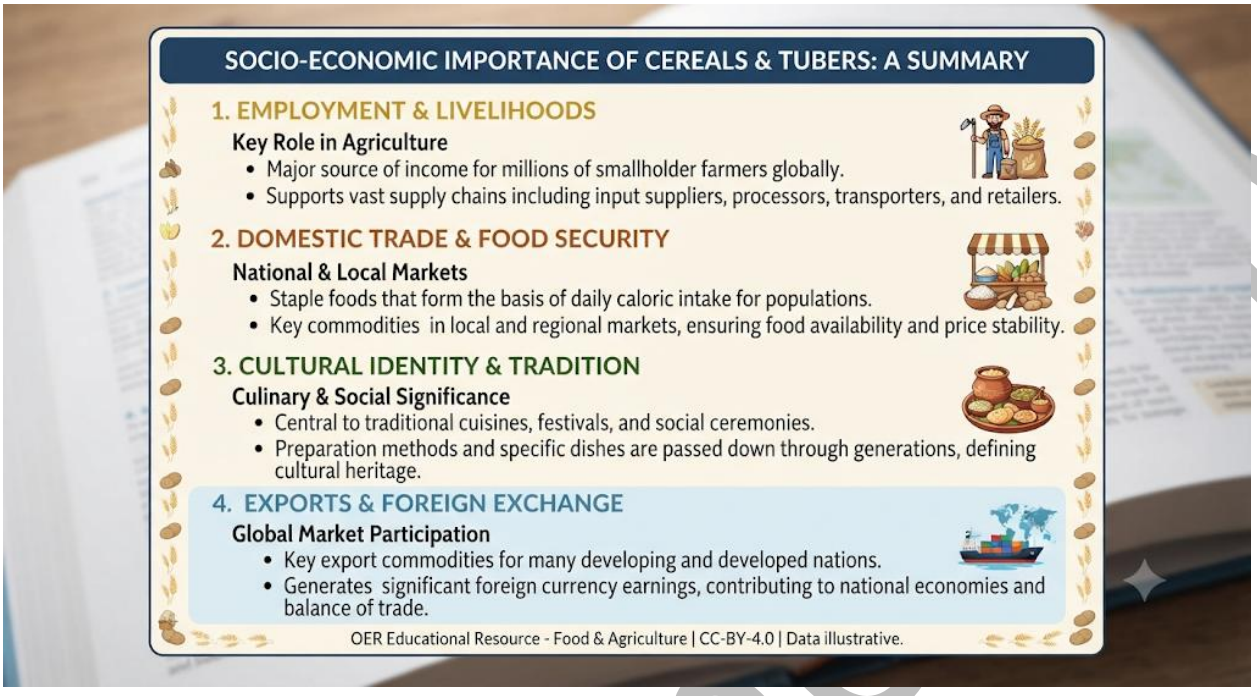

Box 1.3 Socio-economic roles of cereals and tubers

Fill in the blank: Yam festivals in West Africa celebrate the _____ season.

**Pilot questions 1.4**

1. What term is used to describe foods consumed regularly to meet daily energy needs?
2. Give one example of an industrial application of cereals.
3. Which tuber is commonly used to produce starch for thickening?
4. How do cereals and tubers contribute to employment opportunities?
5. Name one cultural event that highlights the socio-economic importance of tubers.

**Series Summary**

This Series has introduced you to the fundamental aspects of cereals and tubers, emphasising their botanical characteristics, composition, comparative features, and roles in food systems. The purpose was to provide a strong foundation for understanding these staple crops, which are central to food security, nutrition, and industrial applications.

We began by examining their **botanical classification and morphology**, then explored their **nutritional, physical, and functional properties**. Following that, we engaged in a **comparative analysis**, highlighting similarities and differences in composition and processing, and finally considered their **significance as staple foods, their industrial applications, and socio-economic importance**. By connecting these discussions to the Series Learning Outcomes, you

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should now be able to define their botanical features, explain their properties, analyse their comparative roles, and evaluate their importance in food systems.

**Glossary of Terms**

- **Bran**: The outer covering of a cereal grain, rich in fibre and nutrients.
- **Cereals**: Grasses cultivated for their edible grains, belonging to the family Poaceae.
- **Composite flour**: A mixture of flours from cereals and tubers, often used to reduce reliance on wheat.
- **Endosperm**: The starchy portion of a cereal grain that provides energy.
- **Functional properties**: Characteristics of food components that affect their behaviour during preparation and processing, such as gelatinisation or gluten formation.
- **Gluten**: A protein complex in wheat that gives dough elasticity and allows bread to rise.
- **Morphology**: The external and internal structure of plants or plant parts.
- **Staple food**: A food consumed regularly and in large quantities to meet daily energy needs.
- **Tubers**: Enlarged underground storage organs of plants, usually formed from stems or roots, rich in starch.

**Concept Check Questions [Series 1]**

**Objective questions**

1. Cereals belong to which botanical family? (Linked to SLO 1.1)
2. Which amino acid is deficient in most cereals? (Linked to SLO 1.2)
3. Cassava must be processed to remove which compounds? (Linked to SLO 1.3)

**Short-answer questions**

4. Explain one similarity between cereals and tubers in terms of structure. (Linked to SLO 1.3)
5. State one socio-economic role of cereals and tubers in developing regions. (Linked to SLO 1.4)

**Long-answer questions**

6. Analyse the differences in composition and processing between cereals and tubers, giving examples. (Linked to SLO 1.3)
    - *Basic response*: Learners should describe protein and carbohydrate differences, and outline milling versus peeling/fermentation.

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- *Value-added response*: Outstanding learners may also discuss implications for product development, such as composite flours and detoxification processes.

7. Evaluate the role of cereals and tubers in food systems, considering their staple significance, industrial applications, and socio-economic importance. (Linked to SLO 1.4)
    - *Basic response*: Learners should mention staple diets, flour and starch production, and employment.
    - *Value-added response*: Outstanding learners may connect these roles to global food security, cultural identity, and economic trade.

**Answers to Concept Check Questions [Series 1]**

1. Poaceae (grass family)
2. Lysine
3. Cyanogenic compounds
4. Both store starch in specialised tissues for energy.
5. They provide employment and support cultural traditions.
6. *Basic*: Cereals have more protein, tubers are mainly carbohydrate; cereals are milled, tubers are peeled, fermented, or boiled. *Value-added*: Composite flours combine strengths, cassava detoxification ensures safety.
7. *Basic*: They are staples, used industrially, and support livelihoods. *Value-added*: They underpin food security, cultural identity, and international trade.

**Answers to Pilot Questions [Series 1]**

1. Poaceae
2. Stem tubers: yam; root tubers: cassava
3. Bran, endosperm, germ
4. Cocoyam
5. Yam has nodes and internodes; cassava is cylindrical with rough skin
6. Carbohydrates
7. Cereals
8. Moisture content affects shelf life
9. Gluten
10. Carbohydrates

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11. Cereals
12. Cyanogenic compounds
13. Gluten
14. Wheat and cassava
15. Staple foods
16. Flour production
17. Food industry
18. They provide employment for farmers and processors
19. Yam festivals

**References and Attributions [Series 1]**

- Figures, plates, tables, and boxes were suggested as placeholders with AI prompts for generation. For example: “Create a labelled diagram showing classification of cereals by family and genus” (Figure 1.1).
- Suggested open educational resource (OER) search strings included: “classification of cereals Poaceae diagram OER”, “nutritional composition cereals tubers OER table”, “applications cereals tubers food technology diagram OER”.
- AI-generated placeholders were designed to illustrate concepts such as cereal grain morphology, tuber examples, and industrial applications.
- Attribution: Content developed from course outline provided in FST 501: Cereals and Tubers Technology.

# Series 2: Flour Milling Processes

**Series outline**

- **2.1 Principles of Flour Milling**
    - 2.1.1 Historical development of milling
    - 2.1.2 Basic principles of size reduction
    - 2.1.3 Modern milling technologies

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- **2.2 Milling of Cereals**
    - 2.2.1 Wheat milling
    - 2.2.2 Maize milling
    - 2.2.3 Sorghum and millet milling
    - 2.2.4 Rice milling
- **2.3 Milling of Tubers**
    - 2.3.1 Cassava processing into flour
    - 2.3.2 Yam flour production
    - 2.3.3 Cocoyam flour production
- **2.4 Quality Control in Milling**
    - 2.4.1 Physical and chemical quality parameters
    - 2.4.2 Safety and hygiene in milling operations
    - 2.4.3 Storage and packaging of milled products

**Introduction**

Flour milling is one of the most important processes in food technology, as it transforms raw cereals and tubers into usable forms for consumption and industrial applications. From bread and pasta to cassava flour and gari, the products of milling are central to diets and economies worldwide. Understanding the principles and methods of flour milling will help you appreciate how raw crops are converted into safe, nutritious, and versatile food products.

The aim of this Series is to introduce you to the principles and practices of flour milling, focusing on both cereals and tubers, and to enable you to evaluate the quality control measures that ensure safe and high-quality milled products.

We shall commence this Series by exploring the **principles of flour milling**, including its historical development, basic concepts of size reduction, and modern technologies. Next, we will examine the **milling of cereals**, such as wheat, maize, sorghum, millet, and rice. Following that, we will consider the **milling of tubers**, including cassava, yam, and cocoyam. Finally, we will wrap up with a discussion on **quality control in milling**, covering physical and chemical parameters, safety and hygiene, and storage and packaging of milled products.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

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- **SLO 2.1** explain the principles of flour milling, including historical development, size reduction, and modern technologies,
- **SLO 2.2** describe the milling processes of major cereals such as wheat, maize, sorghum, millet, and rice,
- **SLO 2.3** outline the milling processes of tubers including cassava, yam, and cocoyam,
- **SLO 2.4** evaluate quality control measures in milling, including physical and chemical parameters, safety, hygiene, and packaging.

## 2.1 Principles of Flour Milling

### 2.1.1 Historical development of milling

The practice of **milling** refers to the process of grinding cereals and tubers into flour or meal. Historically, milling began with simple stone tools used to crush grains, evolving into hand-operated querns and later water- and wind-powered mills. These early methods were labour-intensive but marked the beginning of flour as a staple product. The industrial revolution introduced mechanised roller mills, which greatly improved efficiency and consistency. Today, milling is a highly specialised process that combines traditional knowledge with modern technology.

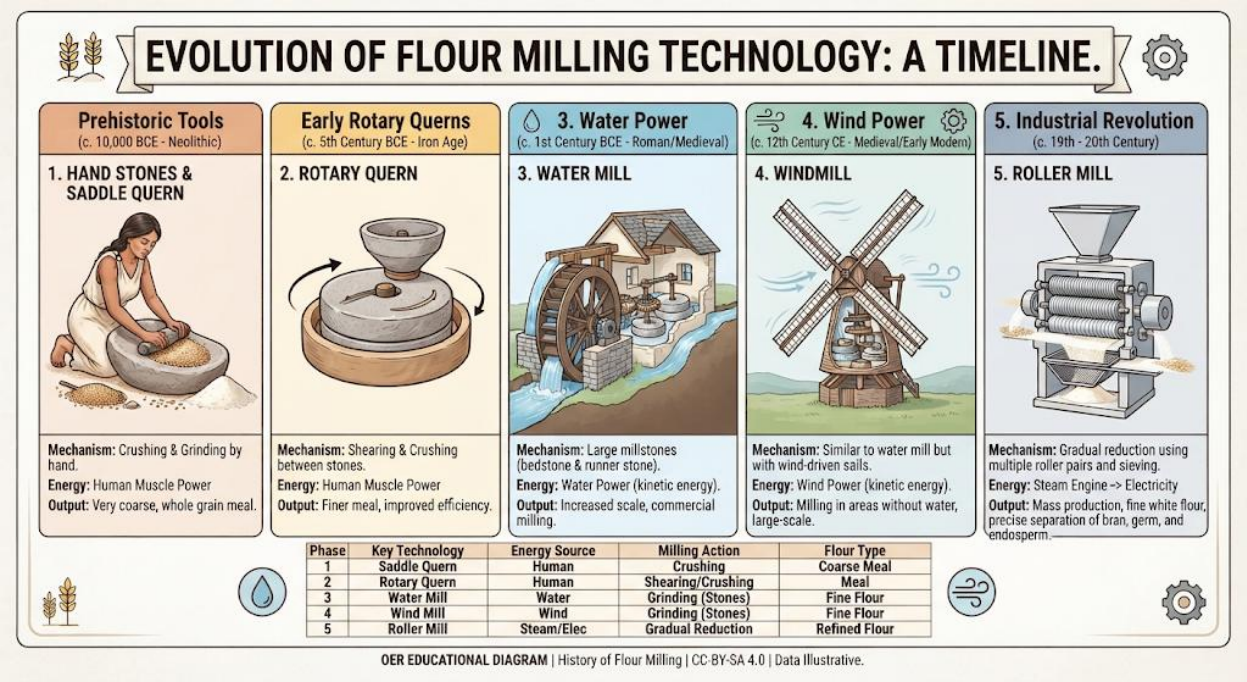


Diagram showing the evolution of milling from stone tools to roller mills Caption: Figure 2.1 Historical development of milling

Fill in the blank: The industrial revolution introduced _____ mills, which improved efficiency and consistency.

### 2.1.2 Basic principles of size reduction

The core principle of milling is **size reduction**, which means breaking down large particles into smaller ones to produce flour. This is achieved through mechanical forces such as compression, impact, and shear. For cereals, the aim is to separate the bran, germ, and endosperm, while for tubers, the goal is to reduce the starchy tissues into fine flour. The efficiency of size reduction depends on factors such as moisture content, hardness of the grain or tuber, and the type of milling equipment used.

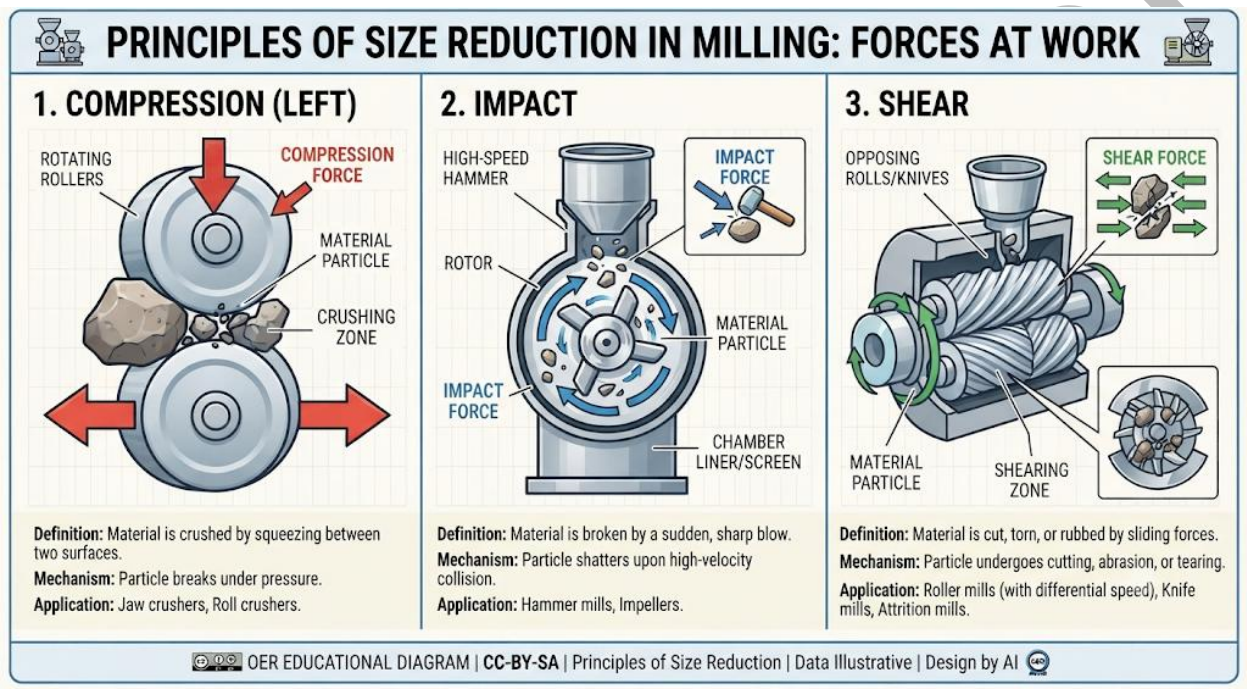


Diagram showing mechanical forces in size reduction (compression, impact, shear) Caption: Figure 2.2 Principles of size reduction in milling

Fill in the blank: The three main mechanical forces used in size reduction are compression, impact, and _____.

### 2.1.3 Modern milling technologies

Modern milling technologies combine precision engineering with automation to produce high-quality flour. Roller mills are widely used for cereals, where grains pass through pairs of rotating cylinders that crush and separate components. Hammer mills and attrition mills are common for tubers, reducing them into fine powders. Advanced technologies also include pneumatic conveying systems, sifters, and electronic sensors that monitor particle size and quality. These innovations ensure efficiency, safety, and consistency in flour production.

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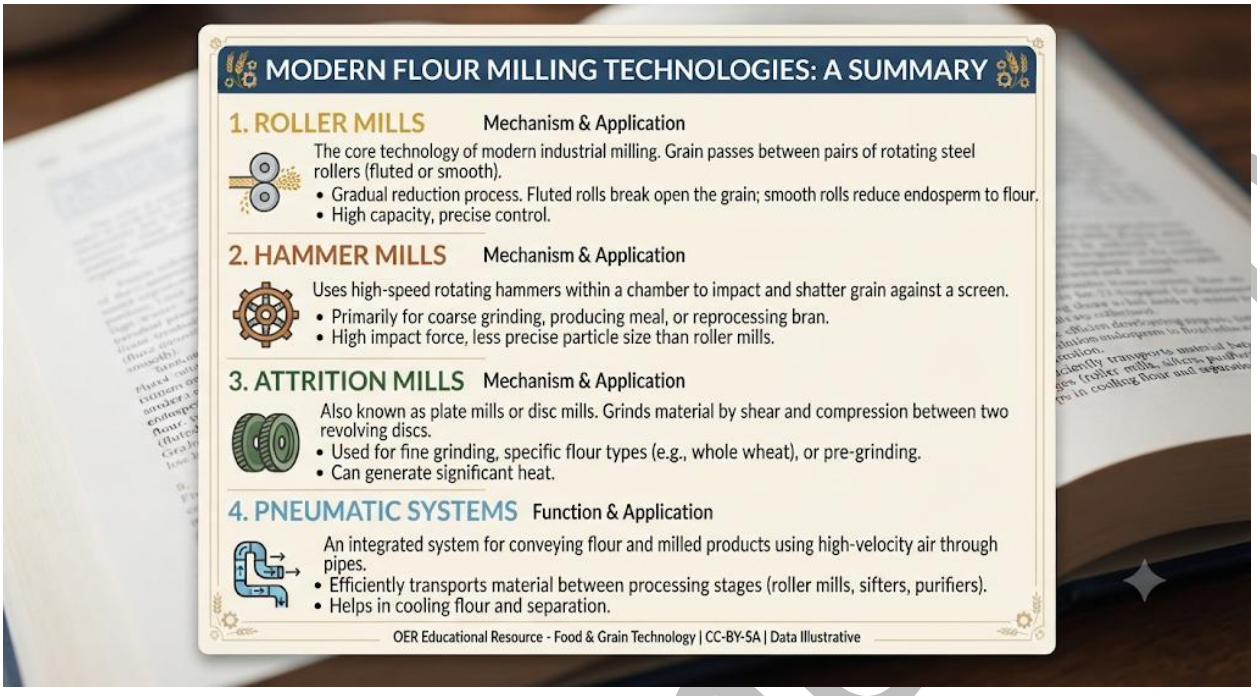

Box 2.1 Modern milling technologies

Fill in the blank: Roller mills use rotating _____ to crush and separate cereal grains.

**Pilot questions 2.1**

1. What is the term used to describe the process of grinding cereals and tubers into flour?
2. Which type of mill was introduced during the industrial revolution?
3. Name the three mechanical forces involved in size reduction.
4. What is the main aim of cereal milling in terms of grain components?
5. Give one example of modern milling technology used for tubers.

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**2.2 Milling of Cereals**

**2.2.1 Wheat milling**

**Wheat milling** is the most advanced and widely studied cereal milling process. The grain is cleaned to remove impurities, then conditioned with water to toughen the bran and soften the endosperm. Roller mills are used to break the grain into smaller particles, separating the bran, germ, and endosperm. The endosperm is ground into flour, while bran and germ may be processed into by-products such as animal feed.

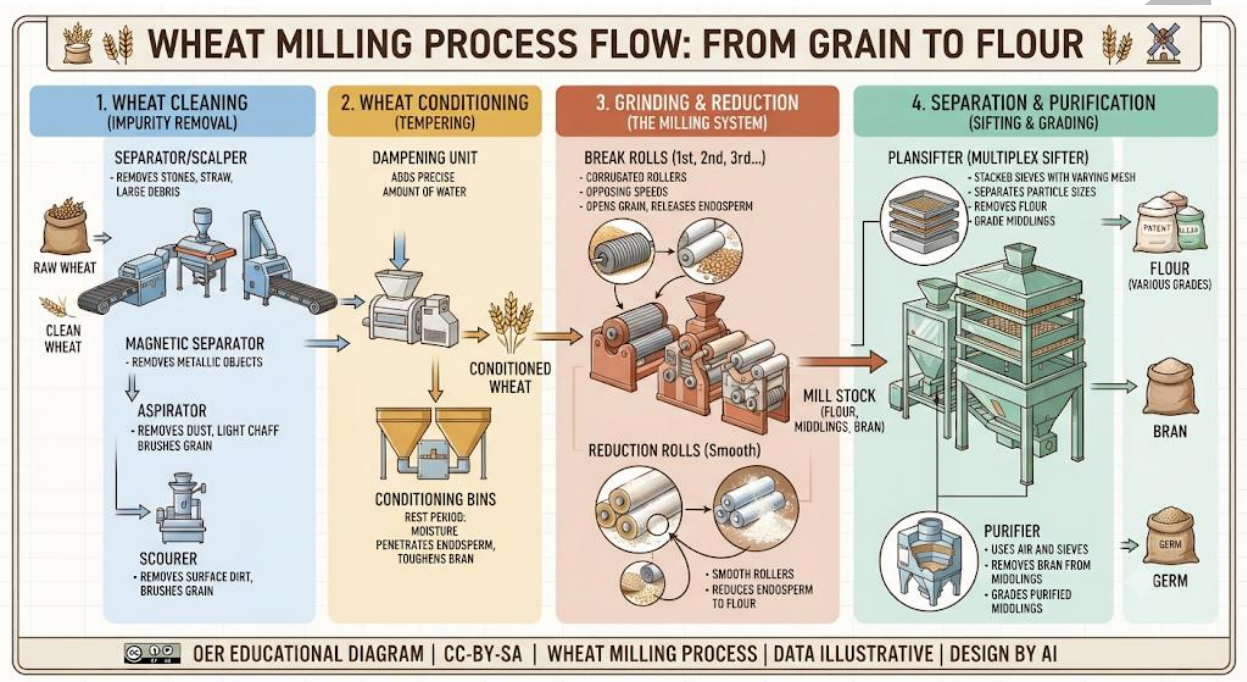


Diagram showing the stages of wheat milling (cleaning, conditioning, grinding, separation) Caption: Figure 2.3 Wheat milling process

Fill in the blank: In wheat milling, the _____ is ground into flour after separation.

### 2.2.2 Maize milling

**Maize milling** involves both dry and wet methods. In dry milling, maize kernels are cleaned and ground into products such as maize flour, grits, and semolina. Wet milling, on the other hand, separates maize into starch, oil, protein, and fibre through soaking and mechanical separation. Wet milling is particularly important for industrial applications, producing starch for sweeteners and bioethanol.

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Image showing maize flour, grits, and starch products Caption: Plate 2.1 Products of maize milling

Fill in the blank: Wet milling of maize produces starch, oil, protein, and _____.

**2.2.3 Sorghum and millet milling**

**Sorghum and millet milling** is often carried out using traditional methods such as pounding or grinding with stone mills. Modern approaches involve dehulling machines that remove the outer husk, followed by grinding into flour. These cereals are important in semi-arid regions due to their drought tolerance. The flour is used for porridge, flatbreads, and fermented beverages.

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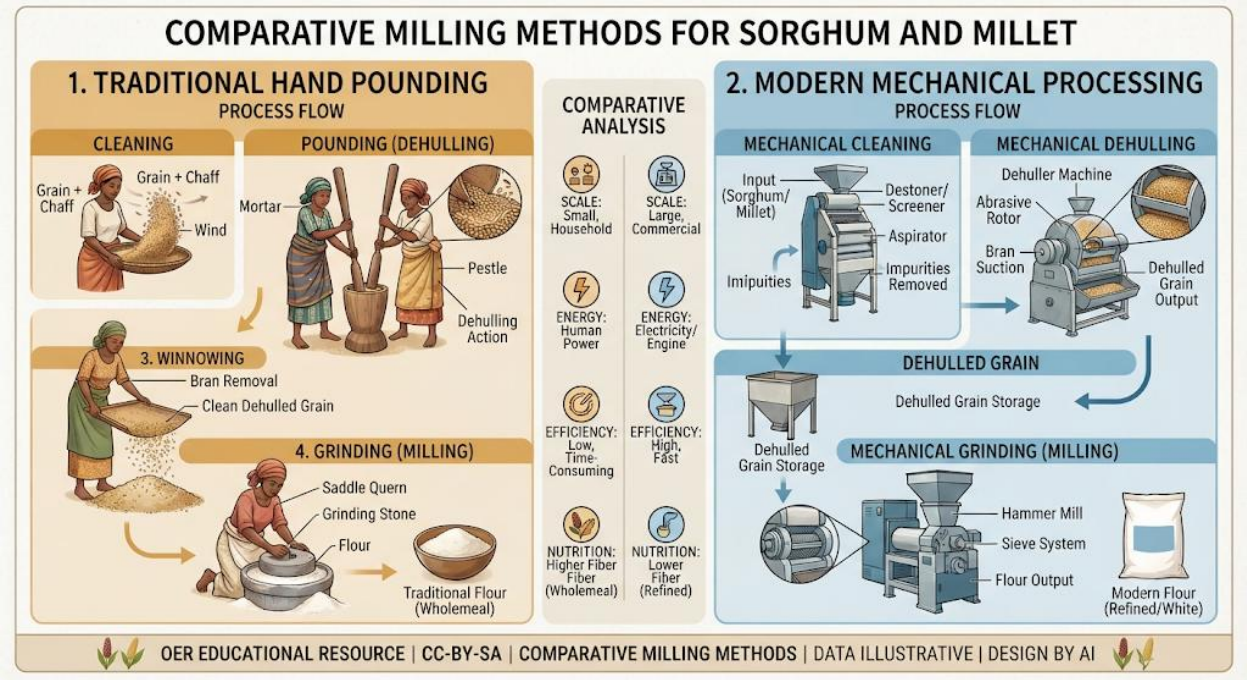


Diagram showing traditional and modern sorghum/millet milling methods Caption: Figure 2.4 Sorghum and millet milling methods

Fill in the blank: Modern sorghum and millet milling often begins with _____ to remove the husk.

### 2.2.4 Rice milling

**Rice milling** is unique because it involves removing the husk and bran layers to produce polished white rice. The process begins with cleaning, followed by dehusking to remove the outer husk. The resulting brown rice may be further milled to remove the bran, producing white rice. By-products such as rice bran are valuable for oil extraction and animal feed.

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Box 2.2 Steps in rice milling

Fill in the blank: Removing the husk from rice produces _____ rice.

**Pilot questions 2.2**

1. What are the three main components separated during wheat milling?
2. Name two products of dry maize milling.
3. Which method is used in modern sorghum and millet milling to remove the husk?
4. What by-product of rice milling is used for oil extraction?
5. Differentiate between dry and wet maize milling in terms of products.

### 2.3 Milling of Tubers

#### 2.3.1 Cassava processing into flour

**Cassava processing** involves several steps to ensure safety and quality. Fresh cassava roots are peeled to remove the outer skin, then washed and grated. The grated pulp is often fermented to reduce cyanogenic compounds, which are naturally present in cassava. After fermentation, the pulp is pressed to remove excess water, dried, and milled into flour. Cassava flour is widely used in products such as gari, fufu, and composite flours.

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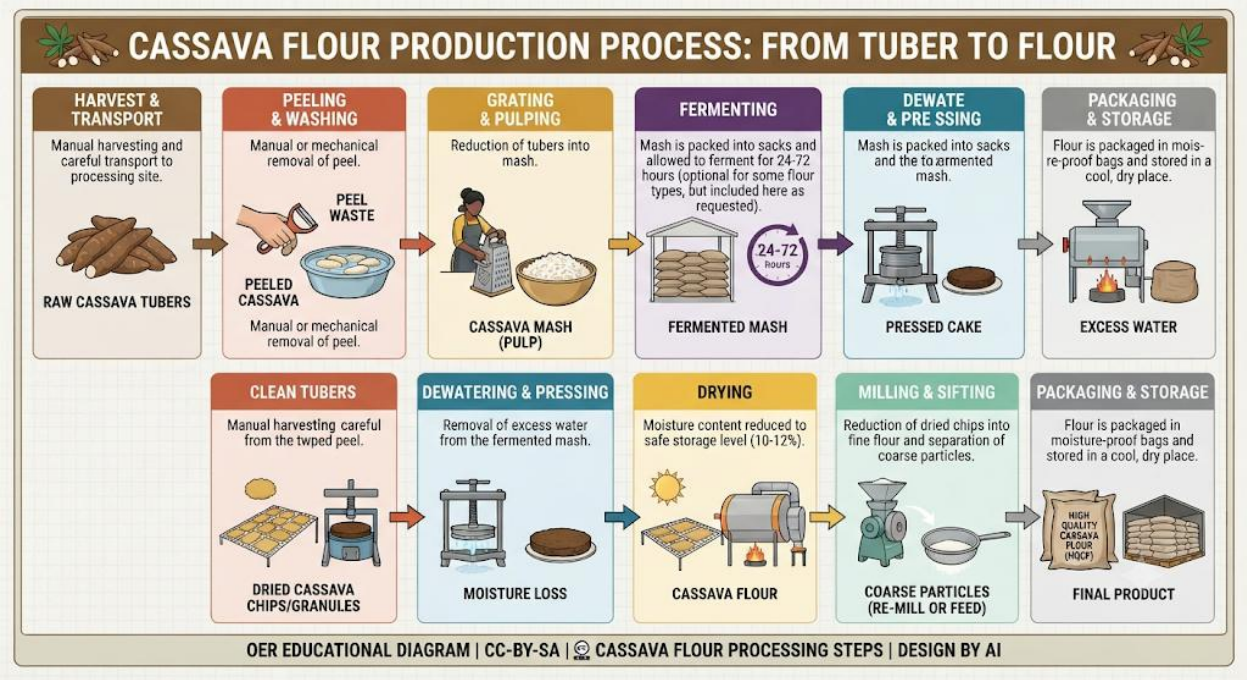


Diagram showing cassava flour production steps (peeling, grating, fermenting, drying, milling)
Caption: Figure 2.5 Cassava flour production process

Fill in the blank: Fermentation of cassava pulp helps to reduce _____ compounds.

### 2.3.2 Yam flour production

**Yam flour production** begins with peeling and slicing fresh yam tubers. The slices are then blanched or parboiled to reduce enzymatic browning, followed by drying to lower moisture content. Once dried, the yam slices are milled into flour, which is commonly used to prepare dishes such as amala. The drying stage is critical, as high moisture content can lead to microbial spoilage and poor flour quality.

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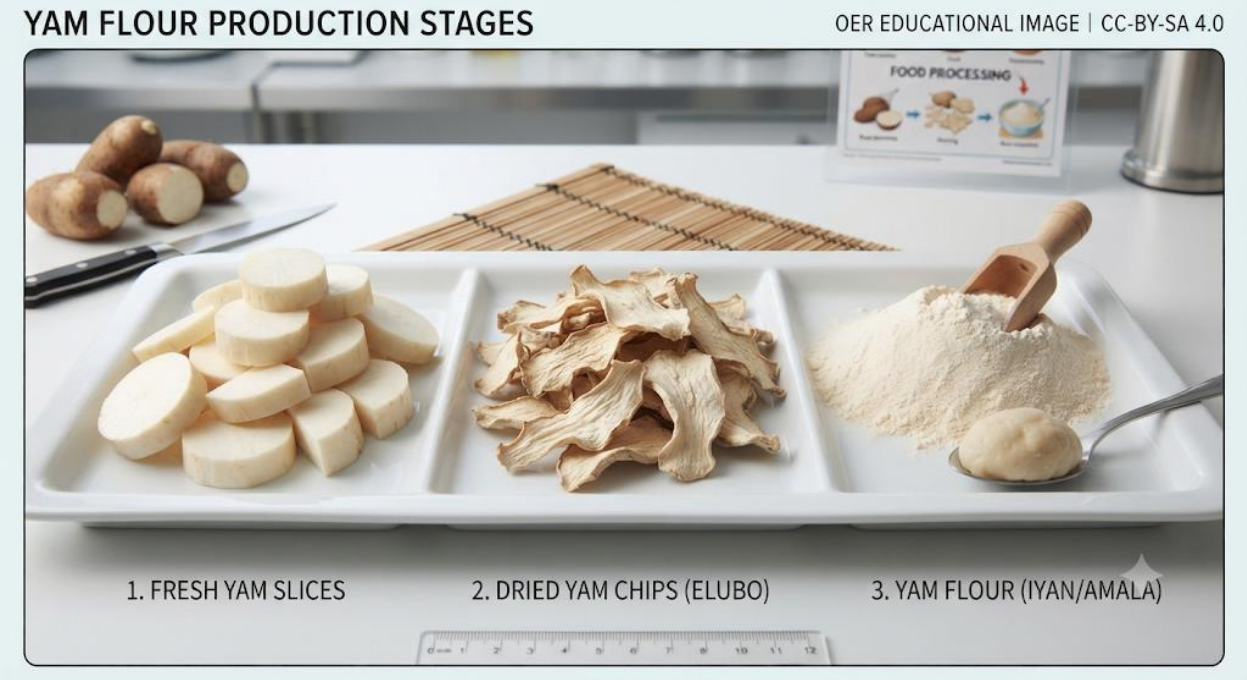


Image showing yam slices, dried yam chips, and yam flour Caption: Plate 2.2 Yam flour production stages

Fill in the blank: The dish commonly prepared from yam flour in Nigeria is called _____.

**2.3.3 Cocoyam flour production**

**Cocoyam flour production** follows similar steps to yam, but cocoyam requires more careful handling due to its smaller size and higher mucilage content. The tubers are peeled, washed, and sliced, then dried thoroughly to prevent microbial growth. Milling produces a fine flour that is used in soups, porridges, and composite flour blends. Cocoyam flour is valued for its digestibility and suitability for infant foods.

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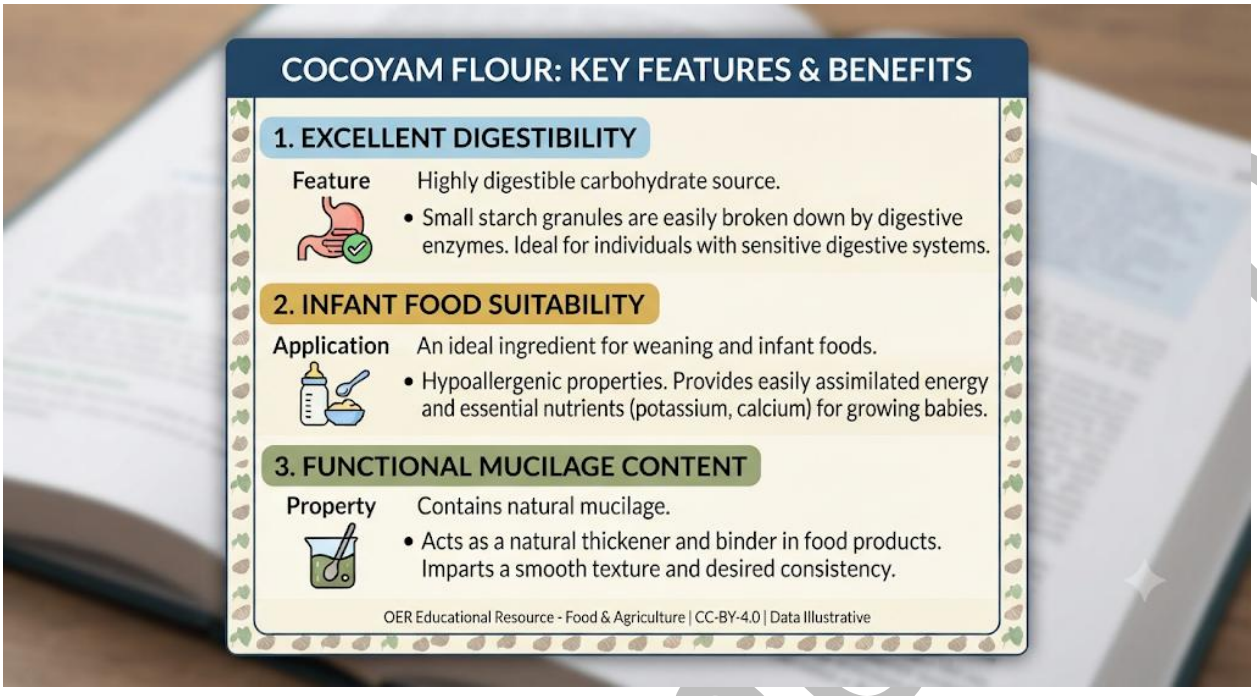


Box 2.3 Key features of cocoyam flour

Fill in the blank: Cocoyam flour is valued for its _____, making it suitable for infant foods.

**Pilot questions 2.3**

1. Why is cassava pulp fermented before milling into flour?
2. What process helps prevent enzymatic browning in yam flour production?
3. Name one traditional Nigerian dish made from yam flour.
4. What characteristic makes cocoyam flour suitable for infant foods?
5. List the main steps in cassava flour production.

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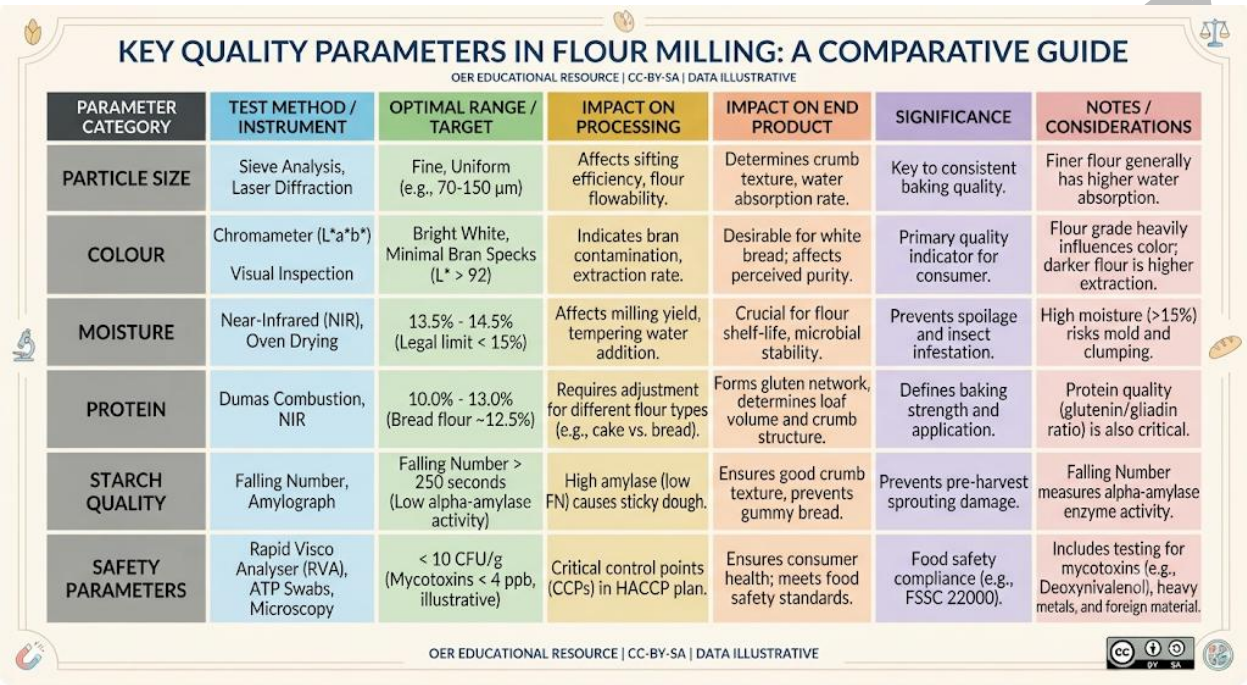
**2.4 Quality Control in Milling**

**2.4.1 Physical and chemical quality parameters**

Quality control in milling ensures that flour and meal products meet acceptable standards for consumption and industrial use. **Physical parameters** include particle size, colour, and moisture content, all of which affect product performance and shelf life. **Chemical parameters** involve protein content, starch quality, and the absence of harmful substances. For example, wheat flour is tested for gluten strength, while cassava flour is checked for residual cyanogenic compounds.



## KEY QUALITY PARAMETERS IN FLOUR MILLING: A COMPARATIVE GUIDE

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| PARAMETER CATEGORY | TEST METHOD / INSTRUMENT | OPTIMAL RANGE / TARGET | IMPACT ON PROCESSING | IMPACT ON END PRODUCT | SIGNIFICANCE | NOTES / CONSIDERATIONS |
|---|---|---|---|---|---|---|
| PARTICLE SIZE | Sieve Analysis, Laser Diffraction | Fine, Uniform (e.g., 70-150 µm) | Affects sifting efficiency, flour flowability. | Determines crumb texture, water absorption rate. | Key to consistent baking quality. | Finer flour generally has higher water absorption. |
| COLOUR | Chromameter (L*a*b*) Visual Inspection | Bright White, Minimal Bran Specks (L* > 92) | Indicates bran contamination, extraction rate. | Desirable for white bread; affects perceived purity. | Primary quality indicator for consumer. | Flour grade heavily influences color; darker flour is higher extraction. |
| MOISTURE | Near-Infrared (NIR), Oven Drying | 13.5% - 14.5% (Legal limit < 15%) | Affects milling yield, tempering water addition. | Crucial for flour shelf-life, microbial stability. | Prevents spoilage and insect infestation. | High moisture (>15%) risks mold and clumping. |
| PROTEIN | Dumas Combustion, NIR | 10.0% - 13.0% (Bread flour ~12.5%) | Requires adjustment for different flour types (e.g., cake vs. bread). | Forms gluten network, determines loaf volume and crumb structure. | Defines baking strength and application. | Protein quality (glutenin/gliadin ratio) is also critical. |
| STARCH QUALITY | Falling Number, Amylograph | Falling Number > 250 seconds (Low alpha-amylase activity) | High amylase (low FN) causes sticky dough. | Ensures good crumb texture, prevents gummy bread. | Prevents pre-harvest sprouting damage. | Falling Number measures alpha-amylase enzyme activity. |
| SAFETY PARAMETERS | Rapid Visco Analyser (RVA), ATP Swabs, Microscopy | < 10 CFU/g (Mycotoxins < 4 ppb, illustrative) | Critical control points (CCPs) in HACCP plan. | Ensures consumer health; meets food safety standards. | Food safety compliance (e.g., FSSC 22000). | Includes testing for mycotoxins (e.g., Deoxynivalenol), heavy metals, and foreign material. |

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Comparison of physical and chemical quality parameters in flour milling Caption: Table 2.1 Physical and chemical quality parameters in flour milling

Fill in the blank: Wheat flour is tested for _____ strength as part of chemical quality control.

### 2.4.2 Safety and hygiene in milling operations

Maintaining **safety and hygiene** is critical in milling operations to prevent contamination and ensure consumer health. Milling facilities must follow strict cleaning routines, pest control measures, and equipment maintenance schedules. Workers are trained to handle raw materials safely, and protective clothing is often required. Hygiene practices also include preventing cross-contamination between different types of flour, such as wheat and cassava.

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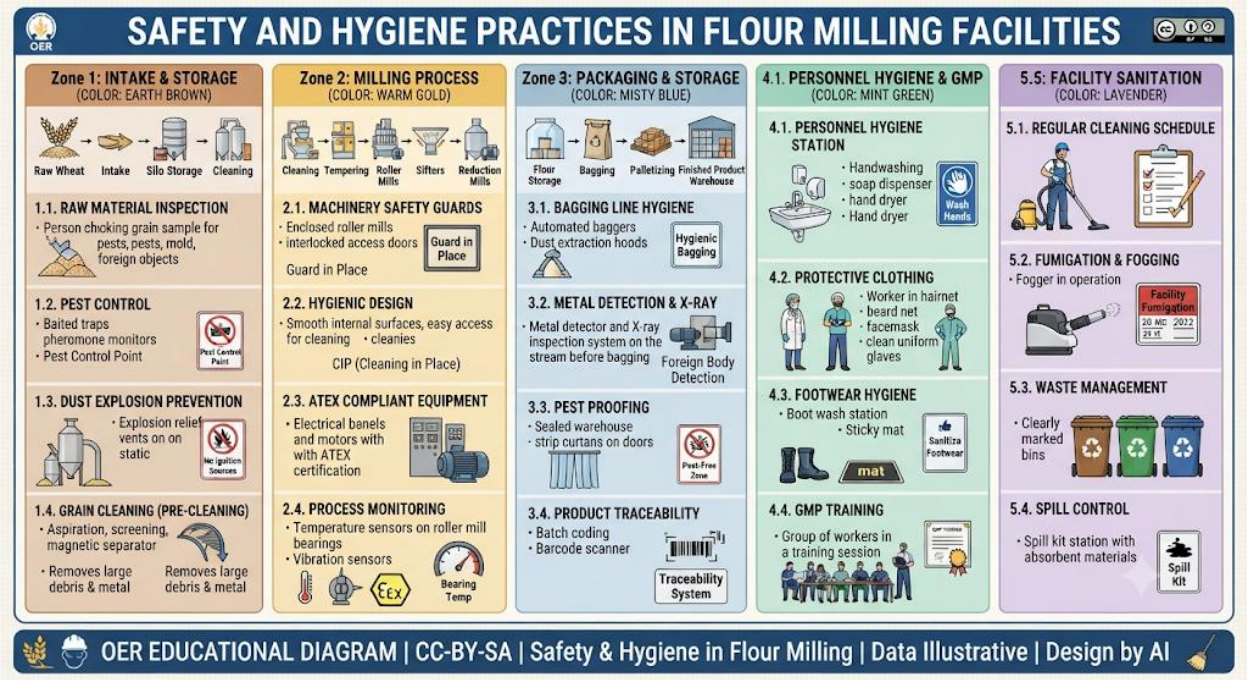


Diagram showing safety and hygiene practices in milling facilities Caption: Figure 2.6 Safety and hygiene practices in milling operations

Fill in the blank: Preventing _____ contamination between different flours is an important hygiene practice.

### 2.4.3 Storage and packaging of milled products

Proper **storage and packaging** are essential to preserve the quality of milled products. Flour and meal should be stored in clean, dry, and pest-free environments. Packaging materials must protect against moisture, insects, and physical damage. Common packaging includes paper bags, plastic sacks, and hermetic containers. Labelling is also important, providing information on product type, weight, and expiry date. Effective storage and packaging extend shelf life and maintain consumer trust.

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Image showing packaged flour products in different materials Caption: Plate 2.3 Storage and packaging of flour products

Fill in the blank: Packaging materials must protect flour against moisture, insects, and _____ damage.

**Pilot questions 2.4**

1. Name two physical parameters checked during flour quality control.
2. What chemical parameter is tested in wheat flour to assess baking quality?
3. Why is hygiene important in milling operations?
4. Give one example of a packaging material used for flour.
5. What information should be included on flour packaging labels?

**Series Summary**

This Series has guided you through the essential processes of flour milling, highlighting its relevance to food technology and product development. We began with the **principles of flour milling**, tracing its historical development, explaining the basics of size reduction, and introducing modern technologies. We then examined the **milling of cereals**, including wheat, maize, sorghum, millet, and rice, before moving on to the **milling of tubers** such as cassava, yam, and cocoyam. Finally, we considered **quality control in milling**, focusing on physical and chemical parameters, safety and hygiene, and storage and packaging.

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By connecting these discussions to the Series Learning Outcomes, you should now be able to explain the principles of milling, describe cereal and tuber milling processes, and evaluate quality control measures. This knowledge provides a strong foundation for understanding how raw crops are transformed into safe, nutritious, and versatile flour products.

**Glossary of Terms**

- **Attrition mill**: A milling device that reduces particle size by rubbing or grinding action.
- **Cassava fermentation**: A process used to reduce cyanogenic compounds in cassava before milling.
- **Cocoyam flour**: Fine flour produced from cocoyam tubers, valued for digestibility and infant food suitability.
- **Conditioning**: The process of adding moisture to wheat grains before milling to toughen the bran and soften the endosperm.
- **Dry milling**: A method of maize milling that produces flour, grits, and semolina without soaking.
- **Endosperm**: The starchy portion of cereal grains that is milled into flour.
- **Hammer mill**: A milling device that uses rotating hammers to crush tubers or grains into fine particles.
- **Moisture content**: The amount of water present in flour or raw materials, affecting shelf life and quality.
- **Roller mill**: A modern milling device that uses rotating cylinders to crush and separate cereal grains.
- **Wet milling**: A maize milling method that separates starch, oil, protein, and fibre through soaking and mechanical separation.

**Concept Check Questions [Series 2]**

**Objective questions**

1. Which type of mill was introduced during the industrial revolution? (Linked to SLO 2.1)
2. What are the three mechanical forces involved in size reduction? (Linked to SLO 2.1)
3. Wet milling of maize produces starch, oil, protein, and _____. (Linked to SLO 2.2)

**Short-answer questions**

4. Explain the purpose of conditioning in wheat milling. (Linked to SLO 2.2)
5. State one reason why cassava pulp is fermented before milling. (Linked to SLO 2.3)

**Long-answer questions**

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6. Describe the steps involved in rice milling and explain the importance of by-products. (Linked to SLO 2.2)
    - *Basic response*: Learners should outline cleaning, dehusking, polishing, and mention rice bran as a by-product.
    - *Value-added response*: Outstanding learners may discuss rice bran oil extraction and its economic significance.
7. Evaluate the importance of quality control in flour milling, considering physical, chemical, safety, and packaging aspects. (Linked to SLO 2.4)
    - *Basic response*: Learners should mention particle size, protein content, hygiene, and packaging materials.
    - *Value-added response*: Outstanding learners may connect quality control to consumer trust, international trade, and food safety regulations.

**Answers to Concept Check Questions [Series 2]**

1. Roller mill
2. Compression, impact, shear
3. Fibre
4. Conditioning toughens the bran and softens the endosperm for easier separation.
5. To reduce cyanogenic compounds and ensure safety.
6. *Basic*: Cleaning, dehusking, polishing; rice bran used for oil extraction. *Value-added*: Rice bran oil contributes to economic value and animal feed.
7. *Basic*: Quality control ensures correct particle size, protein content, hygiene, and packaging. *Value-added*: It builds consumer trust, supports trade, and aligns with food safety standards.

**Answers to Pilot Questions [Series 2]**

**Part 2.1**

1. Milling
2. Roller mills
3. Compression, impact, shear
4. To separate bran, germ, and endosperm
5. Hammer mill

**Part 2.2**

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1. Bran, germ, endosperm
2. Maize flour, grits
3. Dehulling
4. Rice bran
5. Dry milling produces flour/grits; wet milling produces starch, oil, protein, fibre

**Part 2.3**

1. To reduce cyanogenic compounds
2. Blanching/parboiling
3. Amala
4. Digestibility
5. Peeling, washing, grating, fermenting, drying, milling

**Part 2.4**

1. Particle size, moisture content
2. Gluten strength
3. To prevent contamination and ensure consumer health
4. Paper bags, plastic sacks, hermetic containers
5. Product type, weight, expiry date

**References and Attributions [Series 2]**

- Figures, plates, tables, and boxes were suggested as placeholders with AI prompts for generation. For example: “Create a labelled diagram showing cassava flour production steps: peeling, grating, fermenting, drying, milling” (Figure 2.5).
- Suggested open educational resource (OER) search strings included: “wheat milling process diagram OER”, “maize milling products OER image”, “rice milling process OER summary”, “quality parameters flour milling OER table”.
- AI-generated placeholders were designed to illustrate concepts such as historical development of milling, cereal and tuber milling processes, and quality control practices.
- Attribution: Content developed from course outline provided in FST 501: Cereals and Tubers Technology.

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# Series 3: Storage and Preservation

**Series outline**

- **3.1 Principles of Storage and Preservation**
    - 3.1.1 Importance of storage in food systems
    - 3.1.2 Factors affecting shelf life
    - 3.1.3 Principles of preservation
- **3.2 Storage of Cereals**
    - 3.2.1 Traditional storage methods
    - 3.2.2 Modern storage technologies
    - 3.2.3 Challenges in cereal storage
- **3.3 Storage of Tubers**
    - 3.3.1 Traditional storage practices
    - 3.3.2 Modern storage facilities
    - 3.3.3 Post-harvest losses and control
- **3.4 Preservation Techniques**
    - 3.4.1 Physical methods (drying, cooling, irradiation)
    - 3.4.2 Chemical methods (fumigation, preservatives)
    - 3.4.3 Biological methods (fermentation, biocontrol)
- **3.5 Quality Assurance in Storage and Preservation**
    - 3.5.1 Monitoring and evaluation of stored products
    - 3.5.2 Safety and hygiene practices
    - 3.5.3 Packaging and labelling standards

**Introduction**

Effective storage and preservation are vital in maintaining the quality, safety, and availability of cereals and tubers. Without proper handling, these staple crops are prone to spoilage, pest infestation, and nutrient loss, which can lead to significant post-harvest losses and food insecurity.

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By understanding the principles and techniques of storage and preservation, you will be better equipped to ensure that these crops remain safe and nutritious from harvest to consumption.

The aim of this Series is to provide you with knowledge of the principles, methods, and technologies used in the storage and preservation of cereals and tubers, and to enable you to evaluate quality assurance practices that safeguard their value in food systems.

We shall commence this Series by examining the **principles of storage and preservation**, focusing on their importance, factors affecting shelf life, and underlying preservation concepts. Next, we will explore the **storage of cereals**, considering both traditional and modern methods, as well as challenges faced. Following that, we will study the **storage of tubers**, including practices, facilities, and post-harvest loss control. We will then move on to **preservation techniques**, covering physical, chemical, and biological methods. Finally, we will conclude with **quality assurance in storage and preservation**, emphasising monitoring, safety, hygiene, packaging, and labelling standards.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 3.1** explain the principles of storage and preservation, including factors affecting shelf life,
- **SLO 3.2** describe traditional and modern storage methods for cereals and identify associated challenges,
- **SLO 3.3** outline storage practices and facilities for tubers, and analyse post-harvest loss control measures,
- **SLO 3.4** differentiate between physical, chemical, and biological preservation techniques for cereals and tubers,
- **SLO 3.5** evaluate quality assurance practices in storage and preservation, including monitoring, hygiene, packaging, and labelling.

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## 3.1 Principles of Storage and Preservation

### 3.1.1 Importance of storage in food systems

**Storage** refers to the keeping of food products under controlled conditions to maintain their quality and safety until consumption or processing. For cereals and tubers, storage is critical because they are staple foods consumed daily. Proper storage reduces post-harvest losses, ensures year-round

availability, and stabilises food prices. It also supports food security by preventing spoilage and maintaining nutritional value.

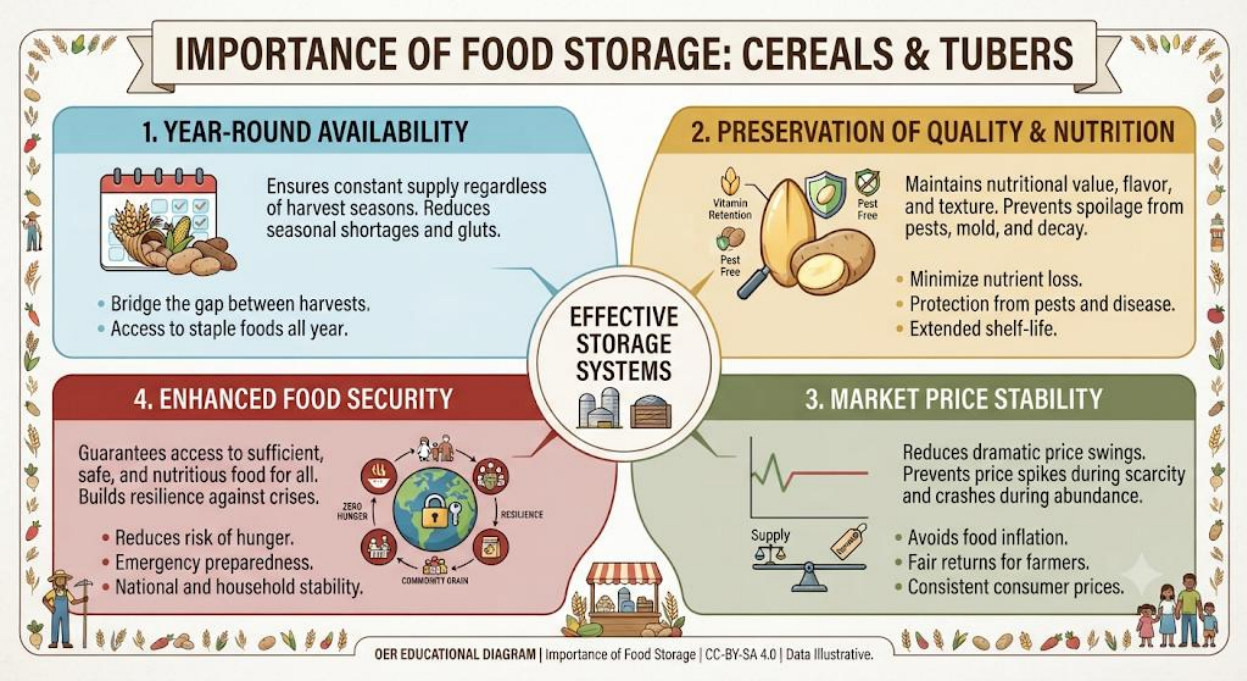

Diagram showing the role of storage in food systems (availability, quality, price stability, food security) Caption: Figure 3.1 Importance of storage in food systems

Fill in the blank: Proper storage of cereals and tubers helps to reduce _____ losses.

### 3.1.2 Factors affecting shelf life

The **shelf life** of cereals and tubers is the period during which they remain safe and suitable for consumption. Shelf life is influenced by factors such as moisture content, temperature, relative humidity, and pest infestation. Cereals with high moisture content are prone to mould growth, while tubers stored in warm, humid conditions may sprout or rot. Effective storage requires controlling these factors to extend shelf life and maintain product quality.

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## KEY FACTORS AFFECTING SHELF LIFE OF CEREALS AND TUBERS

| FACTOR | PARAMETER / DESCRIPTION | OPTIMAL RANGE / CONDITION | IMPACT ON CEREALS | IMPACT ON TUBERS | MECHANISM OF SPOILAGE | MITIGATION STRATEGY |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT | Internal water within the food | Cereals: <12-14% Tubers: >70-80% (but must be controlled externally) | Cereals: High moisture (>14%) leads to mold, sprouting, and insect infestation. | **Tubers:** High moisture leads to rot, sprouting, and weight loss; low moisture leads to shriveling. | Provides water activity (aw) for microbial growth and enzymatic reactions. | Proper drying (cereals), curing and maintaining low relative humidity. |
| TEMPERATURE | Ambient thermal environment | 5°C - 15°C (Illustrative for cool storage; tubers often 2-4°C) | Cereals: High temp increases respiration, insect activity, and fat rancidity. | High temp increases respiration, sprouting, and water loss; low temp (below 2°C) can cause chilling injury | Speeds up or slows down metabolic rates, enzymatic activity, and microbial growth. | Cool storage facilities, good ventilation, and temperature monitoring. |
| RELATIVE HUMIDITY (RH) | Moisture in the surrounding air | 65% - 75% (Illustrative for general storage; tubers often often 85-95% RH) | Cereals: High RH leads to moisture absorption, mold, and mycotoxins | Low RH leads to water loss and shriveling; high RH must be balanced with ventilation to prevent rot | Equilibrium moisture content (EMC) is affected; high RH encourages surface moisture. | Dehumidification (cereals) or humidification (tubers) with airflow |
| PESTS (INSECTS & RODENTS) | Infestation by insects (weevils, beetles) and rodents | <1% infestation level (Illustrative acceptable limit) | Cereals: Significant grain loss, contamination with feces, webs, and insect fragments. | Physical damage, tunneling, and secondary infection **Rodents:** Consumption and extensive damage | Direct consumption and physical damage; introduction of pathogens | Pest-proof storage, good sanitation, fumigation (cereals), and inspection. |

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Factors affecting shelf life of cereals and tubers Caption: Table 3.1 Factors affecting shelf life of cereals and tubers

Fill in the blank: High _____ content in cereals can lead to mould growth.

### 3.1.3 Principles of preservation

**Preservation** involves applying methods to slow down or stop spoilage, thereby extending the usability of food products. The principles of preservation include controlling microbial growth, reducing enzymatic activity, and preventing chemical changes. Techniques such as drying, cooling, and fermentation are applied to cereals and tubers to maintain their quality. Preservation ensures that food remains safe, nutritious, and acceptable to consumers over time.

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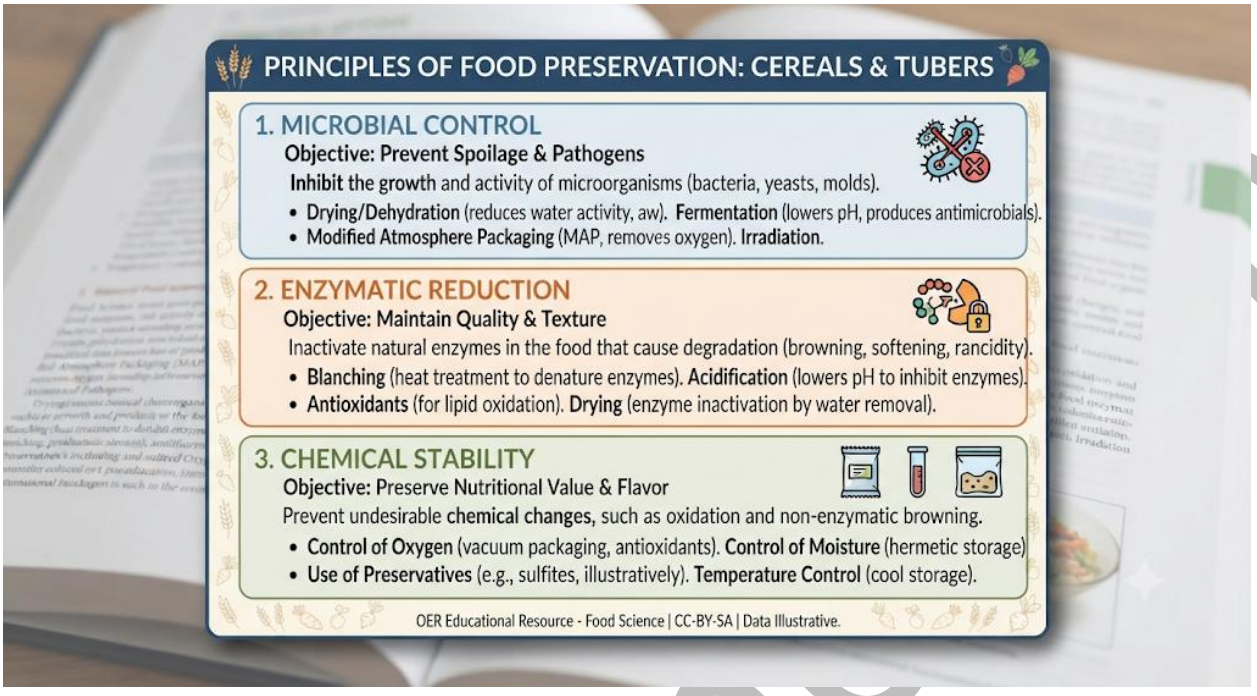

Box 3.1 Principles of preservation

Fill in the blank: Preservation methods aim to control _____ growth and reduce enzymatic activity.

**Pilot questions 3.1**

1. Define storage in the context of food systems.
2. Name two benefits of proper storage of cereals and tubers.
3. List three factors that affect the shelf life of cereals and tubers.
4. What is the main aim of preservation methods?
5. Give one example of a preservation technique used for cereals or tubers.

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**3.2 Storage of Cereals**

### 3.2.1 Traditional storage methods

Traditional methods of **cereal storage** have been used for centuries, particularly in rural communities. These include storing grains in clay pots, woven baskets, or underground pits. While inexpensive and accessible, these methods often expose cereals to pests, moisture, and microbial contamination. Nevertheless, they remain important in regions where modern facilities are unavailable.

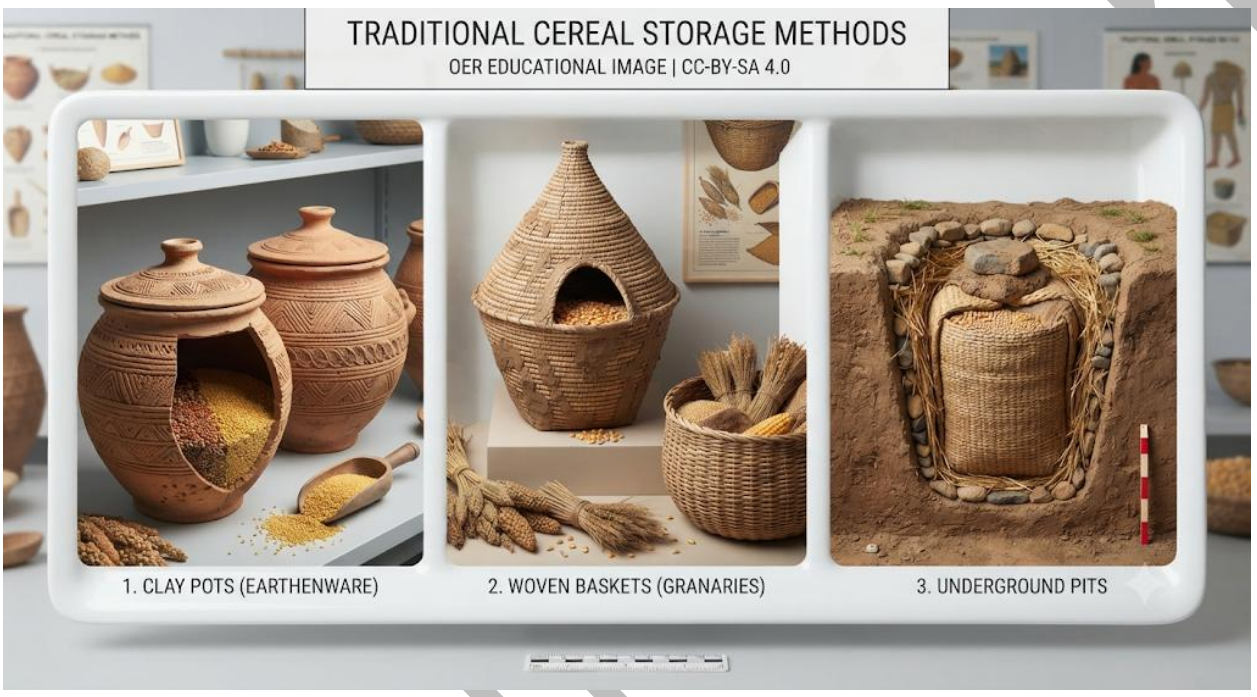


Image showing traditional cereal storage methods (clay pots, baskets, underground pits) Caption: Plate 3.1 Traditional cereal storage methods

Fill in the blank: Traditional cereal storage methods often expose grains to _____ and moisture.

### 3.2.2 Modern storage technologies

Modern cereal storage technologies focus on maintaining grain quality and preventing losses. Common methods include silos, hermetic bags, and controlled atmosphere storage. Silos provide large-scale storage with protection against pests and weather. Hermetic bags are airtight containers that prevent insect infestation without chemicals. Controlled atmosphere storage regulates oxygen and carbon dioxide levels to inhibit microbial growth. These technologies improve shelf life and ensure food safety.

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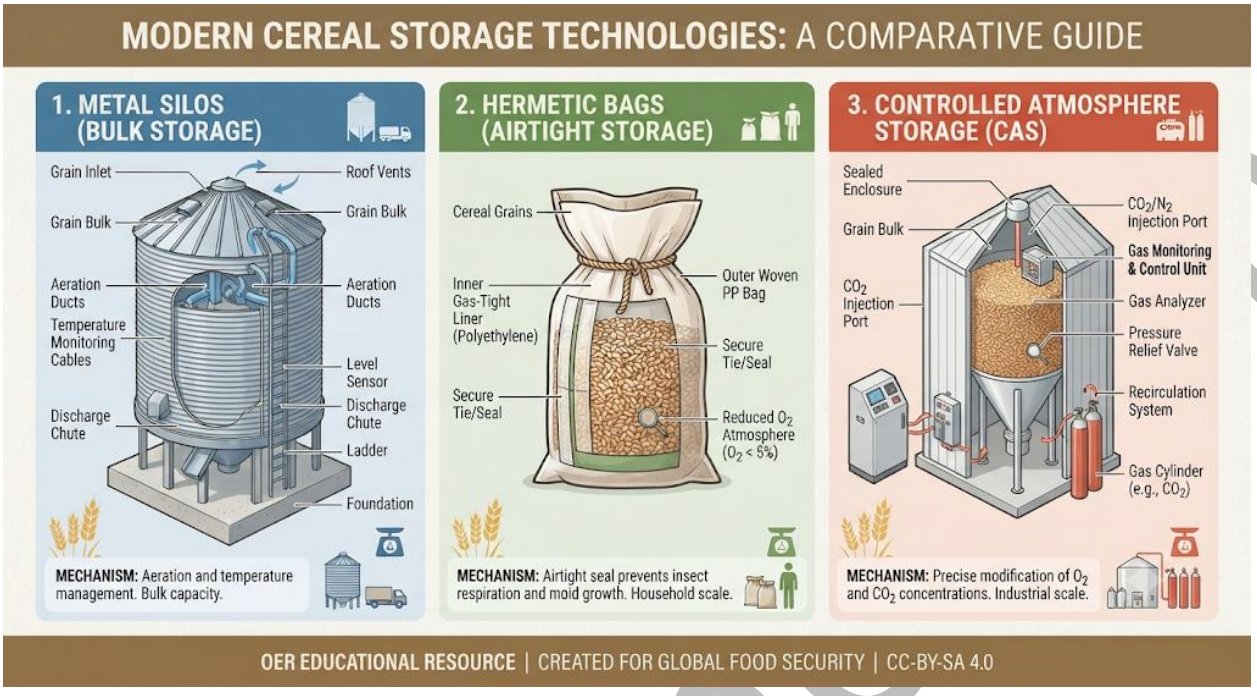


Diagram showing modern cereal storage technologies (silos, hermetic bags, controlled atmosphere) Caption: Figure 3.2 Modern cereal storage technologies

Fill in the blank: Hermetic bags prevent insect infestation by creating an _____ environment.

### 3.2.3 Challenges in cereal storage

Despite advances, cereal storage faces several **challenges**. Pests such as weevils and rodents can cause significant losses. Moisture and humidity may lead to mould growth and mycotoxin contamination, which poses health risks. Inadequate infrastructure and poor handling practices also contribute to post-harvest losses. Addressing these challenges requires investment in modern facilities, farmer training, and effective monitoring systems.

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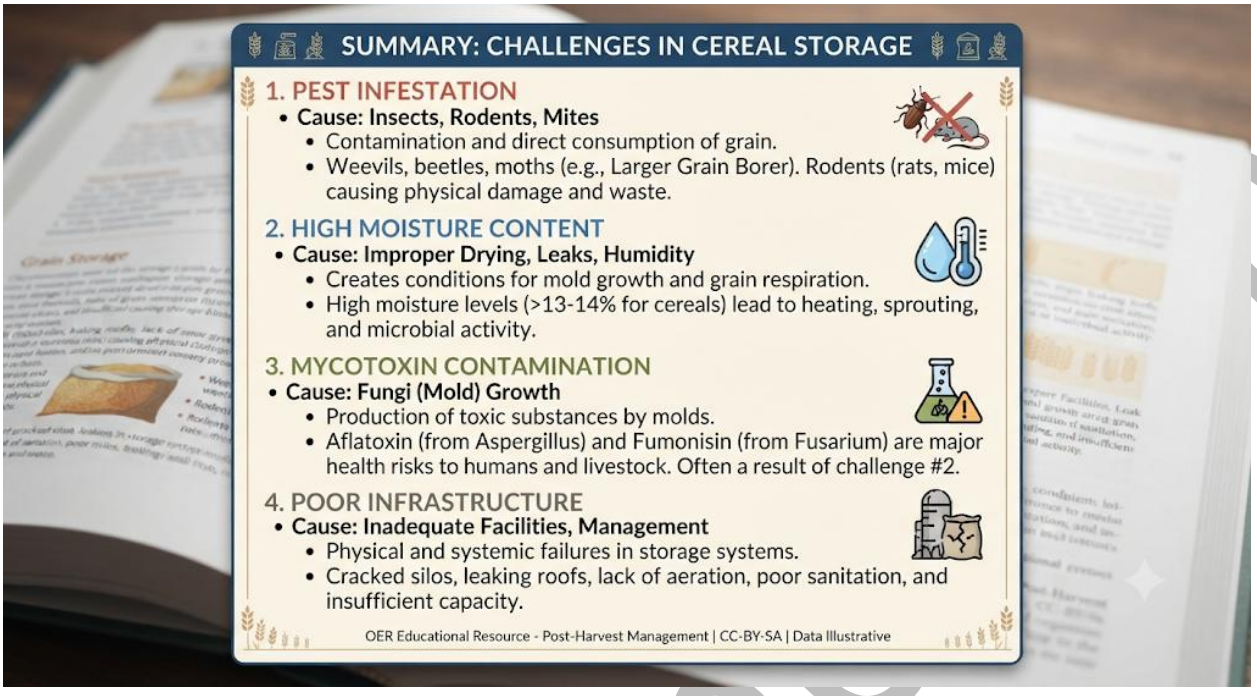

Box 3.2 Challenges in cereal storage

Fill in the blank: Mould growth in cereals can lead to _____ contamination, which is harmful to health.

**Pilot questions 3.2**

1. Name two traditional methods of cereal storage.
2. What is the main advantage of hermetic bags in cereal storage?
3. List two modern technologies used for cereal storage.
4. Identify one health risk associated with poor cereal storage.
5. Suggest one way to address challenges in cereal storage.

### 3.3 Storage of Tubers

#### 3.3.1 Traditional storage practices

Tubers such as yam, cassava, and cocoyam are often stored using **traditional practices**. These include heaping in barns, storing in pits, or keeping under shade in open environments. While these methods are inexpensive and widely used, they expose tubers to pests, sprouting, and microbial spoilage. Traditional storage remains common in rural areas where modern facilities are limited.

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Image showing traditional tuber storage (yam barns, cassava heaps, cocoyam pits) Caption: Plate 3.2 Traditional tuber storage practices

Fill in the blank: Traditional storage of tubers often leads to _____ and microbial spoilage.

**3.3.2 Modern storage facilities**

Modern storage facilities for tubers aim to reduce losses and extend shelf life. Cold storage rooms and ventilated warehouses are commonly used to control temperature and humidity. Controlled atmosphere storage can also be applied to reduce respiration and delay sprouting. These facilities require investment and infrastructure but provide significant benefits in maintaining tuber quality and reducing post-harvest losses.

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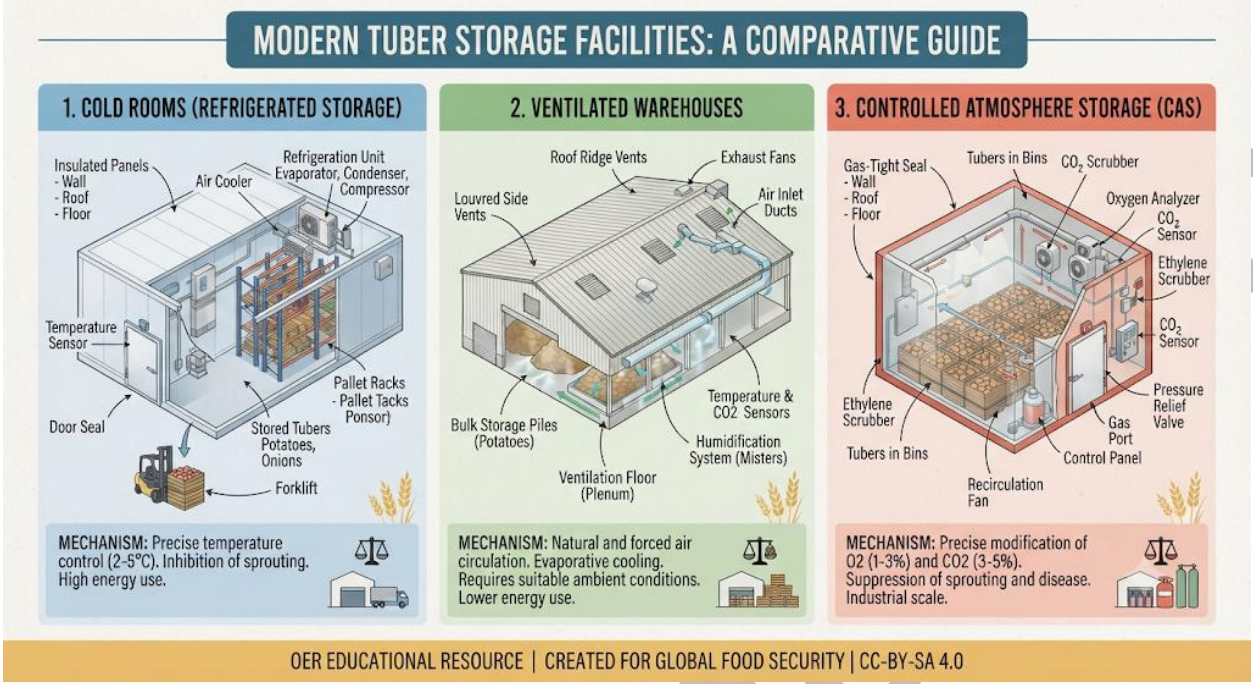


Diagram showing modern tuber storage facilities (cold rooms, ventilated warehouses, controlled atmosphere) Caption: Figure 3.3 Modern tuber storage facilities

Fill in the blank: Cold storage rooms help to control _____ and humidity in tuber storage.

### 3.3.3 Post-harvest losses and control

Tubers are highly perishable and prone to **post-harvest losses** due to sprouting, rotting, and pest attack. Losses can reach up to 40% in some regions if storage is inadequate. Control measures include proper curing of tubers before storage, use of improved packaging materials, and application of safe chemical treatments to reduce microbial growth. Training farmers in handling and storage practices is also essential to minimise losses.

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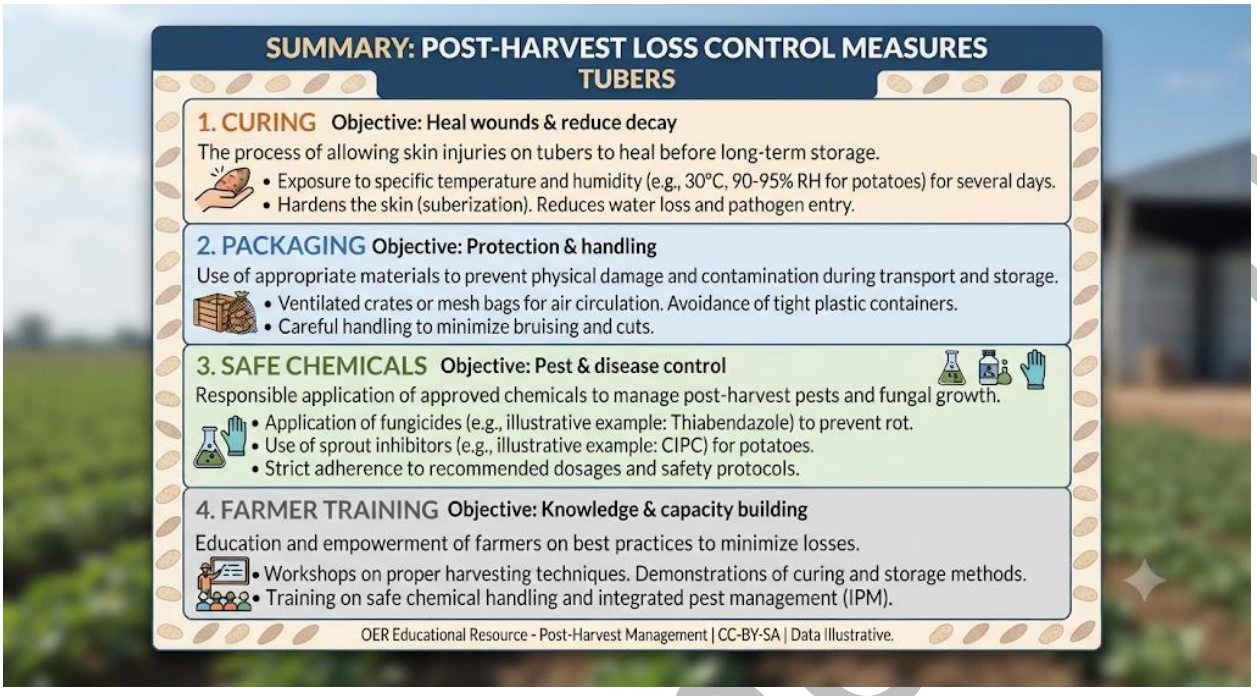

Box 3.3 Post-harvest loss control in tubers

Fill in the blank: Curing tubers before storage helps to reduce _____ and microbial infection.

**Pilot questions 3.3**

1. Name two traditional methods of storing tubers.
2. What is the main advantage of cold storage facilities for tubers?
3. List two causes of post-harvest losses in tubers.
4. How does curing help in tuber storage?
5. Suggest one way farmers can reduce post-harvest losses.

### 3.4 Preservation Techniques

#### 3.4.1 Physical methods

Physical preservation methods rely on altering environmental conditions to slow spoilage. **Drying** reduces moisture content, preventing microbial growth. **Cooling** lowers temperature, slowing respiration and enzymatic activity in tubers. **Irradiation** uses controlled doses of radiation to kill insects and microorganisms in cereals without affecting nutritional quality. These methods are widely used because they are effective and often chemical-free.

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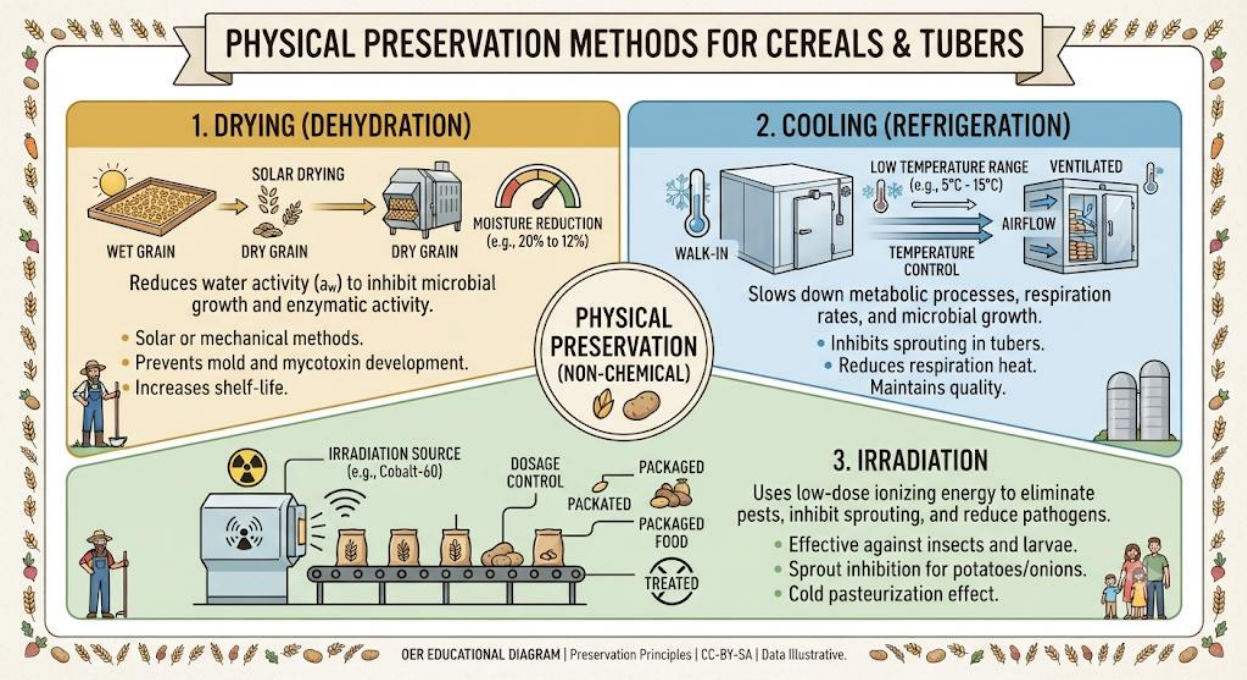


Diagram showing physical preservation methods (drying, cooling, irradiation) Caption: Figure 3.4 Physical preservation methods for cereals and tubers

Fill in the blank: Drying prevents microbial growth by reducing _____ content.

### 3.4.2 Chemical methods

Chemical preservation methods involve applying substances to protect cereals and tubers. **Fumigation** is commonly used in cereal storage to control insect pests, while safe **preservatives** may be applied to reduce microbial spoilage. For tubers, chemical dips or coatings can delay sprouting and rotting. These methods must be carefully regulated to ensure food safety and avoid harmful residues.

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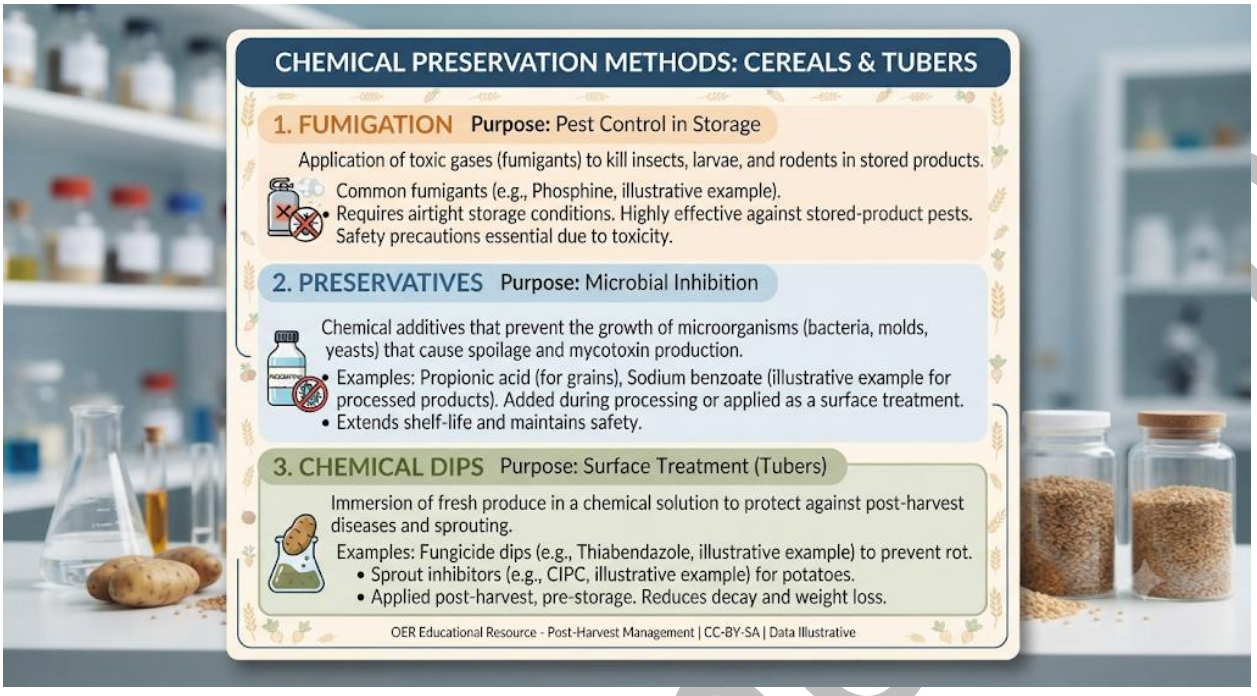

Box 3.4 Chemical preservation methods

Fill in the blank: Fumigation is used in cereal storage to control _____ pests.

### 3.4.3 Biological methods

Biological preservation methods harness natural processes to extend shelf life. **Fermentation** is widely used for cassava, maize, and sorghum, producing products such as gari, ogi, and traditional beers. Fermentation reduces harmful compounds and improves flavour. **Biocontrol** involves using beneficial microorganisms to suppress spoilage organisms or pests. These methods are sustainable and often enhance nutritional and sensory qualities of food.

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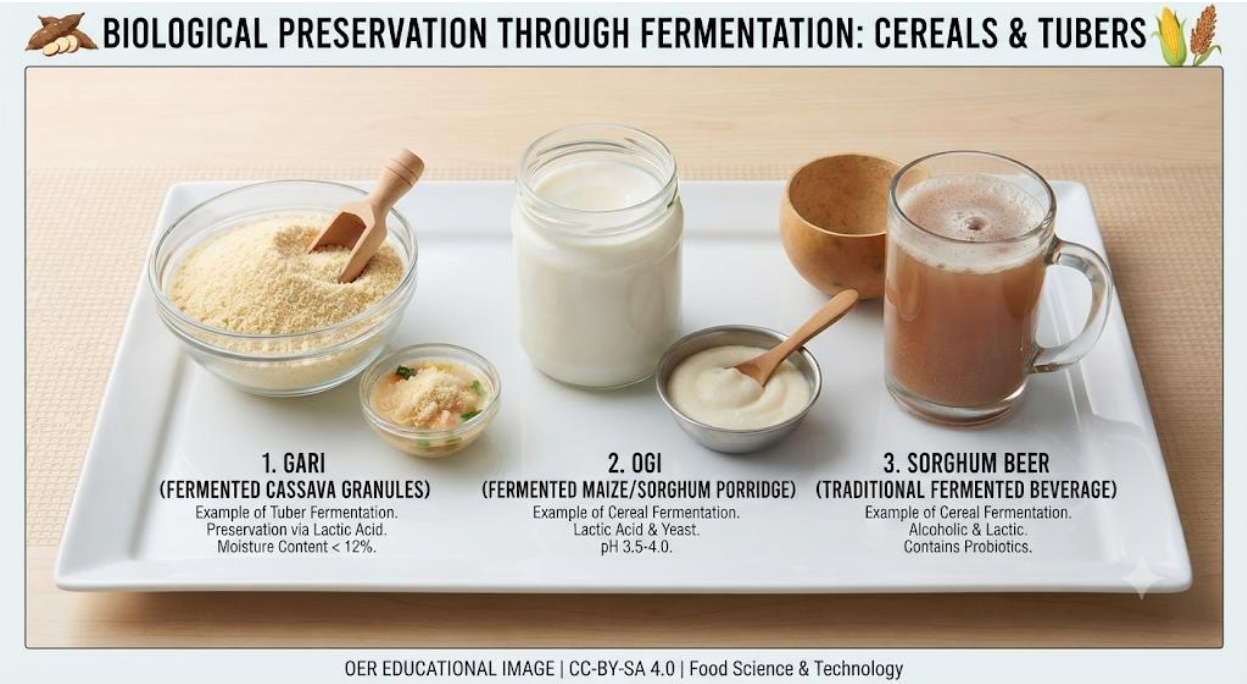


Image showing fermented products (gari, ogi, sorghum beer) Caption: Plate 3.3 Biological preservation methods through fermentation

Fill in the blank: Fermentation of cassava reduces harmful _____ compounds and improves flavour.

**Pilot questions 3.4**

1. Name two physical preservation methods for cereals and tubers.
2. What is the main purpose of fumigation in cereal storage?
3. Give one example of a chemical preservation method used for tubers.
4. Which preservation technique produces gari and ogi from cassava and maize?
5. Explain one advantage of biological preservation methods.

### 3.5 Quality Assurance in Storage and Preservation

#### 3.5.1 Monitoring and evaluation of stored products

**Monitoring and evaluation** are essential to ensure that cereals and tubers remain safe and of high quality during storage. Regular checks for moisture content, pest activity, and signs of spoilage help identify problems early. Grain samples may be tested for mycotoxins, while tubers are inspected for sprouting or rotting. Effective monitoring ensures corrective measures can be taken promptly to reduce losses.

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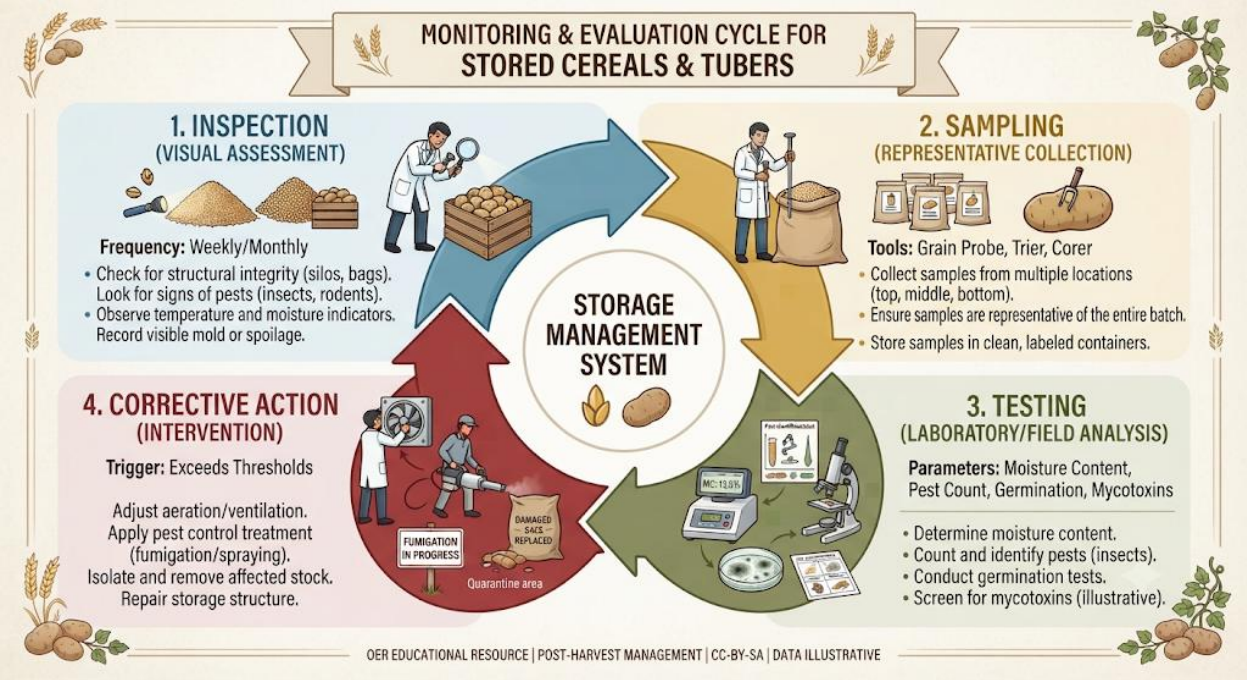


Diagram showing monitoring steps (inspection, sampling, testing, corrective action) Caption: Figure 3.5 Monitoring and evaluation of stored products

Fill in the blank: Grain samples are often tested for _____ to ensure safety during storage.

### 3.5.2 Safety and hygiene practices

Maintaining **safety and hygiene** in storage facilities is critical to prevent contamination. This includes cleaning storage areas, controlling pests, and ensuring workers follow hygiene protocols. Equipment and containers must be sanitised, and cross-contamination between different products should be avoided. Good hygiene practices protect consumers and maintain trust in food systems.

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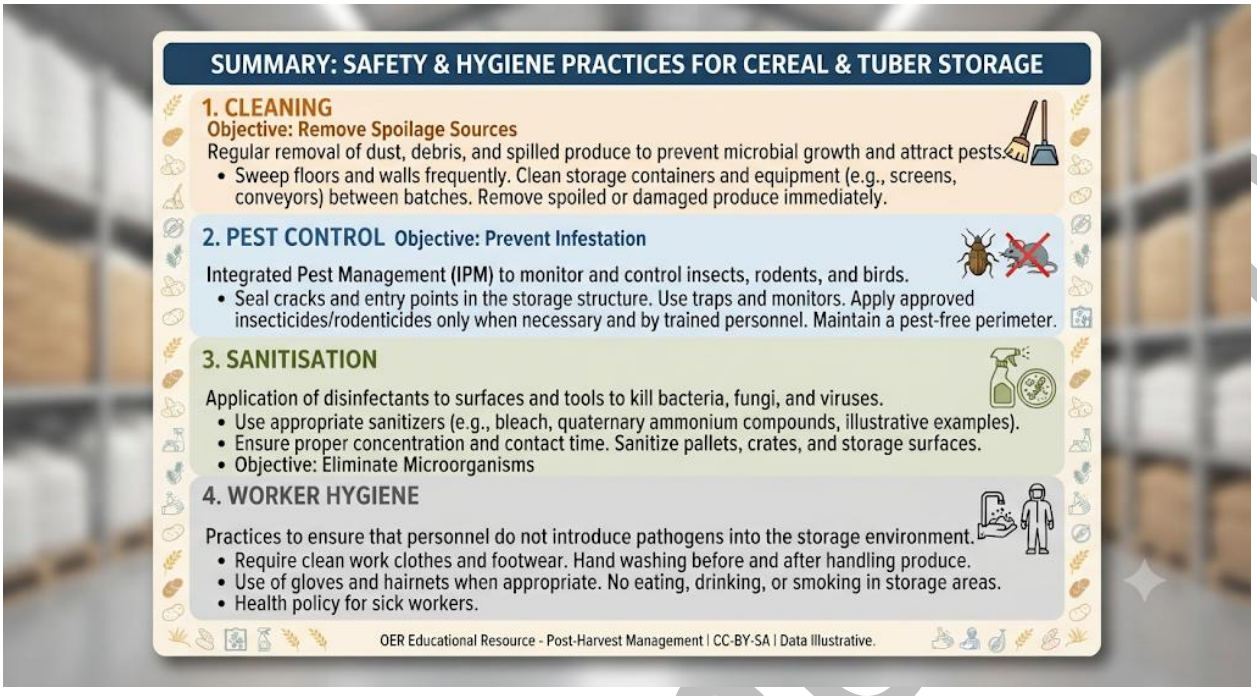


Box 3.5 Safety and hygiene practices in storage

Fill in the blank: Cleaning and sanitising storage equipment helps to prevent _____ contamination.

### 3.5.3 Packaging and labelling standards

**Packaging and labelling** are vital for protecting stored products and providing consumers with accurate information. Packaging materials must shield cereals and tubers from moisture, pests, and physical damage. Labelling should include product name, weight, date of packaging, and expiry date. Adhering to standards ensures product traceability, compliance with regulations, and consumer confidence.

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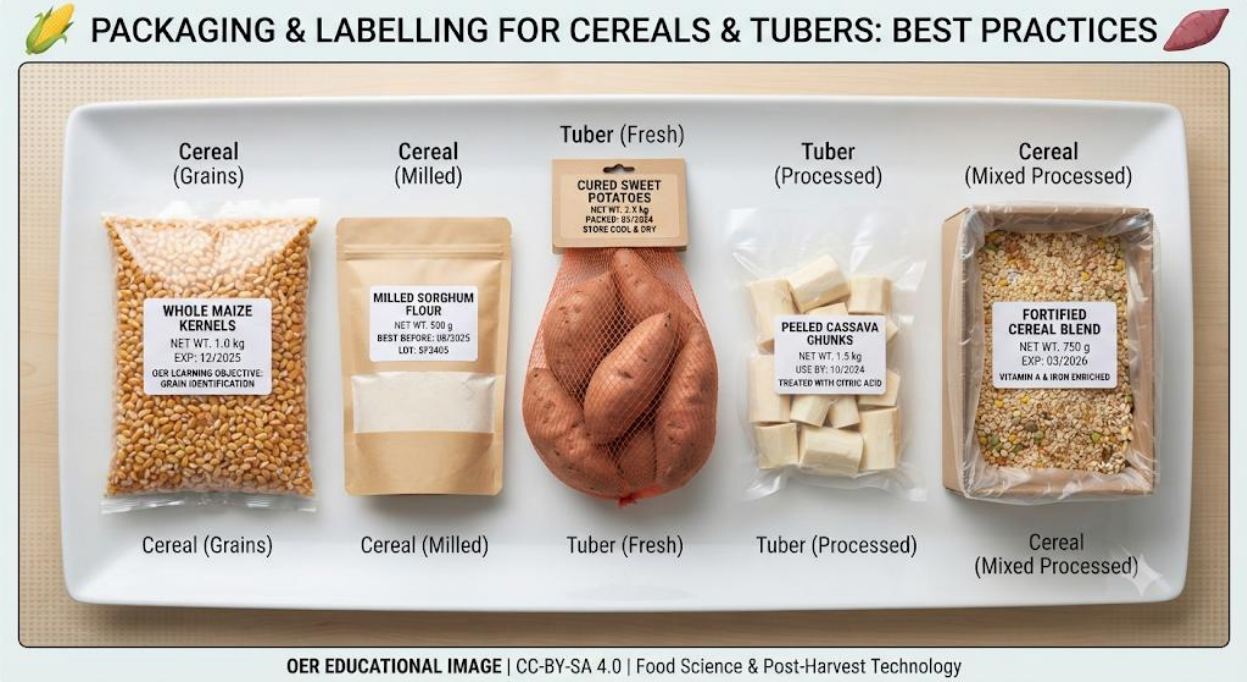


Image showing packaged cereals and tubers with clear labelling Caption: Plate 3.4 Packaging and labelling of stored products

Fill in the blank: Labelling of stored products should include the product name, weight, and _____ date.

**Pilot questions 3.5**

1. What is the purpose of monitoring stored cereals and tubers?
2. Name one safety practice in storage facilities.
3. Why is sanitisation of equipment important in storage?
4. List two pieces of information that should appear on product labels.
5. How does packaging help maintain product quality?

**Series Summary**

This Series has explored the essential aspects of **storage and preservation of cereals and tubers**, emphasising their importance in reducing post-harvest losses and ensuring food security. We began with the **principles of storage and preservation**, highlighting factors that affect shelf life. We then examined the **storage of cereals**, comparing traditional methods with modern technologies and identifying challenges. Following that, we studied the **storage of tubers**, considering traditional practices, modern facilities, and post-harvest loss control. We also discussed **preservation techniques**, including physical, chemical, and biological methods, and concluded with **quality assurance**, focusing on monitoring, safety, hygiene, packaging, and labelling.

By linking these discussions to the Series Learning Outcomes, you should now be able to explain the principles of storage and preservation, describe cereal and tuber storage methods, differentiate preservation techniques, and evaluate quality assurance practices. This knowledge equips you to manage cereals and tubers effectively, ensuring their safety, quality, and availability in food systems.

**Glossary of Terms**

- **Controlled atmosphere storage**: A method of storage where oxygen and carbon dioxide levels are regulated to slow spoilage.
- **Curing**: The process of drying and hardening tuber skins before storage to reduce microbial infection.
- **Fermentation**: A biological preservation method that uses microorganisms to produce safe, nutritious foods such as gari and ogi.
- **Fumigation**: A chemical preservation method used to control insect pests in stored cereals.
- **Hermetic bags**: Airtight storage containers that prevent insect infestation without chemicals.
- **Moisture content**: The amount of water present in stored products, which affects shelf life and spoilage risk.
- **Mycotoxins**: Harmful compounds produced by moulds in improperly stored cereals.
- **Post-harvest losses**: The reduction in quantity or quality of crops after harvest due to spoilage, pests, or poor handling.
- **Shelf life**: The period during which a food product remains safe and suitable for consumption.
- **Sprouting**: The growth of new shoots in stored tubers, which reduces quality and usability.

**Concept Check Questions [Series 3]**

**Objective questions**

1. High moisture content in cereals can lead to _____ growth. (Linked to SLO 3.1)
2. Which modern storage technology uses airtight containers to prevent insect infestation? (Linked to SLO 3.2)
3. Curing tubers before storage helps to reduce _____ infection. (Linked to SLO 3.3)

**Short-answer questions**

4. State two factors that affect the shelf life of cereals and tubers. (Linked to SLO 3.1)

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5. Give one example of a biological preservation method and its product. (Linked to SLO 3.4)

**Long-answer questions**

6. Compare traditional and modern storage methods for cereals, highlighting advantages and limitations. (Linked to SLO 3.2)
    - *Basic response*: Learners should mention clay pots, pits, silos, and hermetic bags.
    - *Value-added response*: Outstanding learners may discuss cost, accessibility, and food safety implications.
7. Evaluate quality assurance practices in storage and preservation, considering monitoring, hygiene, packaging, and labelling. (Linked to SLO 3.5)
    - *Basic response*: Learners should mention inspection, cleaning, packaging materials, and labelling.
    - *Value-added response*: Outstanding learners may connect these practices to consumer trust, regulatory compliance, and international trade.

**Answers to Concept Check Questions [Series 3]**

1. Mould
2. Hermetic bags
3. Microbial
4. Moisture content, temperature
5. Fermentation – gari or ogi
6. *Basic*: Traditional methods (clay pots, pits) are cheap but prone to pests; modern methods (silos, hermetic bags) are safer but costly. *Value-added*: Modern methods improve food safety and trade potential, while traditional methods remain vital in resource-limited areas.
7. *Basic*: Monitoring ensures safety, hygiene prevents contamination, packaging protects products, and labelling provides information. *Value-added*: These practices build consumer confidence, meet regulatory standards, and support export markets.

**Answers to Pilot Questions [Series 3]**

**Part 3.1**

1. Controlled keeping of food products under safe conditions
2. Reduces losses, ensures year-round availability
3. Moisture, temperature, pests
4. To slow spoilage and maintain quality

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5. Drying

**Part 3.2**

1. Clay pots, underground pits
2. Creates an airtight environment
3. Silos, controlled atmosphere storage
4. Mycotoxin contamination
5. Investment in modern facilities and farmer training

**Part 3.3**

1. Barn storage, pits
2. Controls temperature and humidity
3. Sprouting, rotting
4. Reduces microbial infection
5. Improved packaging and handling practices

**Part 3.4**

1. Drying, cooling
2. To control insect pests
3. Chemical dips or coatings
4. Fermentation
5. Sustainable and enhances flavour/nutrition

**Part 3.5**

1. To maintain safety and quality
2. Pest control
3. Prevents contamination
4. Product name, expiry date
5. Protects against moisture and pests

**References and Attributions [Series 3]**

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- Figures, plates, tables, and boxes were suggested as placeholders with AI prompts for generation. For example: “Create a labelled diagram showing physical preservation methods: drying, cooling, irradiation” (Figure 3.4).
- Suggested open educational resource (OER) search strings included: “importance of food storage cereals tubers diagram OER”, “modern cereal storage technologies diagram OER”, “post-harvest loss control tubers OER summary”, “packaging labelling cereals tubers OER image”.
- AI-generated placeholders were designed to illustrate concepts such as traditional and modern storage methods, preservation techniques, and quality assurance practices.
- Attribution: Content developed from course outline provided in FST 501: Cereals and Tubers Technology.

## Series 4: Composite Flours and Confectionery

**Series outline**

- **4.1 Principles of Composite Flours**
    - 4.1.1 Definition and importance
    - 4.1.2 Nutritional and functional advantages
    - 4.1.3 Limitations and challenges
- **4.2 Preparation of Composite Flours**
    - 4.2.1 Selection of raw materials (cereals, tubers, legumes)
    - 4.2.2 Processing steps (cleaning, drying, milling, blending)
    - 4.2.3 Quality parameters in composite flour formulation
- **4.3 Applications in Confectionery**
    - 4.3.1 Bread and bakery products
    - 4.3.2 Cakes, biscuits, and pastries
    - 4.3.3 Traditional confectionery products
- **4.4 Quality Control and Standards**
    - 4.4.1 Nutritional evaluation

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- 4.4.2 Sensory properties and consumer acceptance
- 4.4.3 Regulatory and safety standards

**Introduction**

Composite flours are blends of wheat flour with flours from other sources such as tubers, legumes, and cereals. They are developed to improve nutritional quality, reduce dependence on wheat imports, and diversify food products. Confectionery, on the other hand, refers to sweet and baked goods such as bread, cakes, biscuits, and pastries, which often rely on flour as their main ingredient. By combining composite flours with confectionery applications, food technologists can create products that are nutritious, affordable, and culturally relevant.

The aim of this Series is to introduce you to the principles, preparation, and applications of composite flours, and to enable you to evaluate their role in confectionery production, including quality control and standards.

We shall commence this Series by examining the **principles of composite flours**, focusing on their definition, importance, advantages, and limitations. Next, we will explore the **preparation of composite flours**, including raw material selection, processing steps, and quality parameters. Following that, we will study the **applications in confectionery**, covering bread, cakes, biscuits, pastries, and traditional products. Finally, we will conclude with **quality control and standards**, emphasising nutritional evaluation, sensory properties, and regulatory requirements.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the principles of composite flours, including their importance, advantages, and limitations,
- **SLO 4.2** describe the preparation of composite flours, including raw material selection, processing, and quality parameters,
- **SLO 4.3** outline the applications of composite flours in confectionery products such as bread, cakes, biscuits, and pastries,
- **SLO 4.4** evaluate quality control measures and standards in composite flour and confectionery production.

**4.1 Principles of Composite Flours**

**4.1.1 Definition and importance**

**Composite flours** are blends of wheat flour with flours from other sources such as tubers (cassava, yam), legumes (soybean, cowpea), and cereals (maize, sorghum, millet). They are important because they reduce dependence on wheat imports, enhance nutritional value, and

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promote the use of locally available crops. Composite flours also support food security and economic sustainability by diversifying raw materials for bakery and confectionery industries.

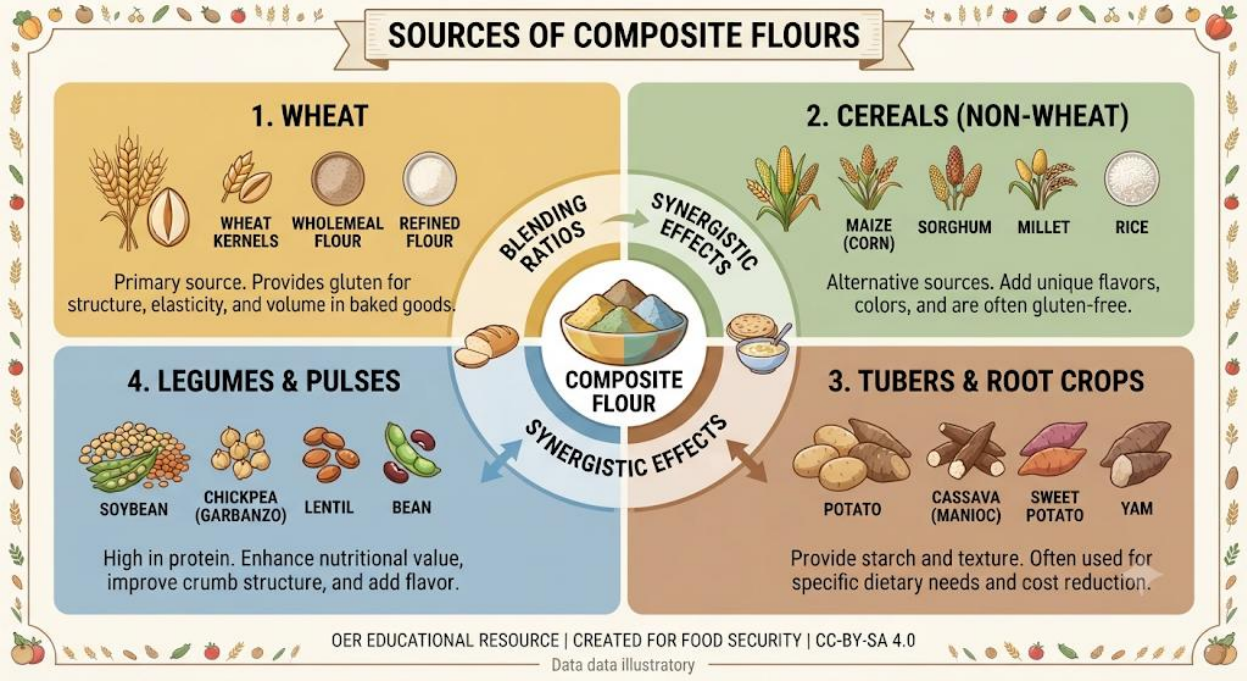


Diagram showing sources of composite flours (wheat, tubers, legumes, cereals) Caption: Figure 4.1 Sources of composite flours

Fill in the blank: Composite flours are blends of wheat flour with flours from _____, legumes, and cereals.

### 4.1.2 Nutritional and functional advantages

Composite flours offer several **nutritional and functional advantages**. Legume flours increase protein content, while tuber flours provide energy-rich starch. Cereals such as sorghum and millet add dietary fibre and micronutrients. Functionally, composite flours can improve water absorption, dough handling, and product diversity. They also allow for gluten reduction in products, making them suitable for consumers with dietary restrictions.

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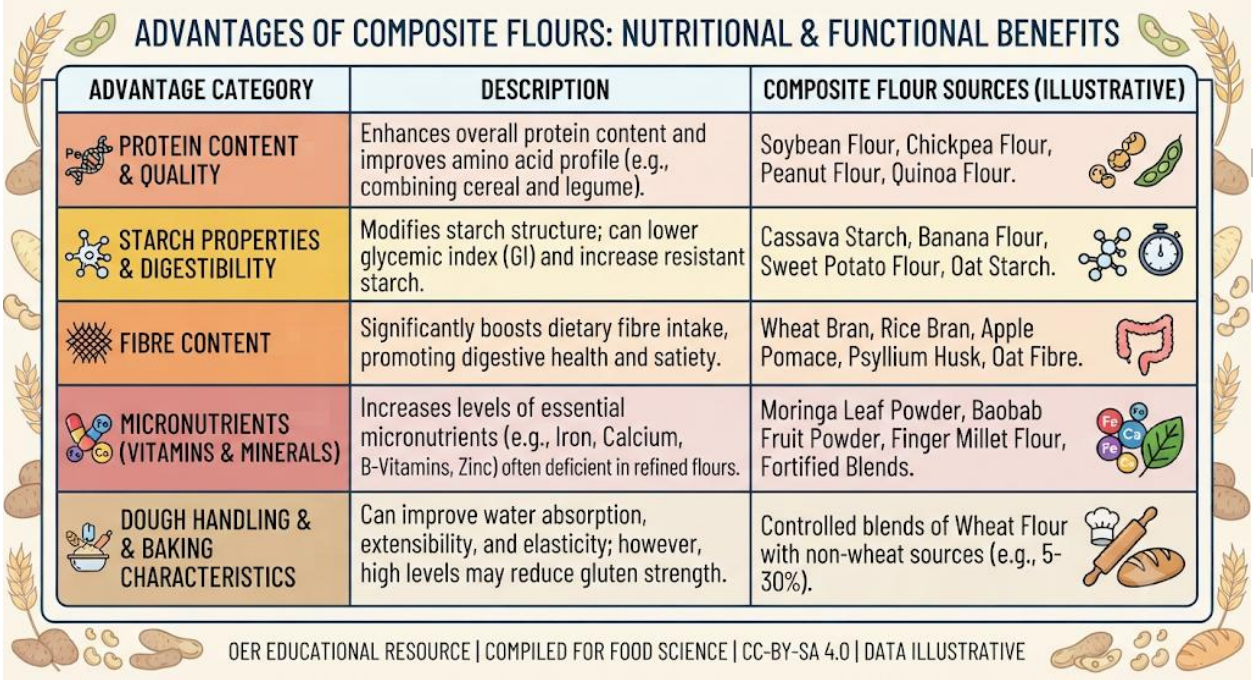


Nutritional and functional advantages of composite flours Caption: Table 4.1 Nutritional and functional advantages of composite flours

Fill in the blank: Legume flours increase the _____ content of composite flours.

**4.1.3 Limitations and challenges**

Despite their benefits, composite flours face **limitations and challenges**. Substituting wheat with non-wheat flours may reduce gluten strength, affecting bread volume and texture. Some tuber flours may impart undesirable flavours or colours. Storage stability can also be an issue, especially with legume flours that are prone to rancidity. Consumer acceptance and regulatory approval are additional challenges that must be addressed for successful adoption.

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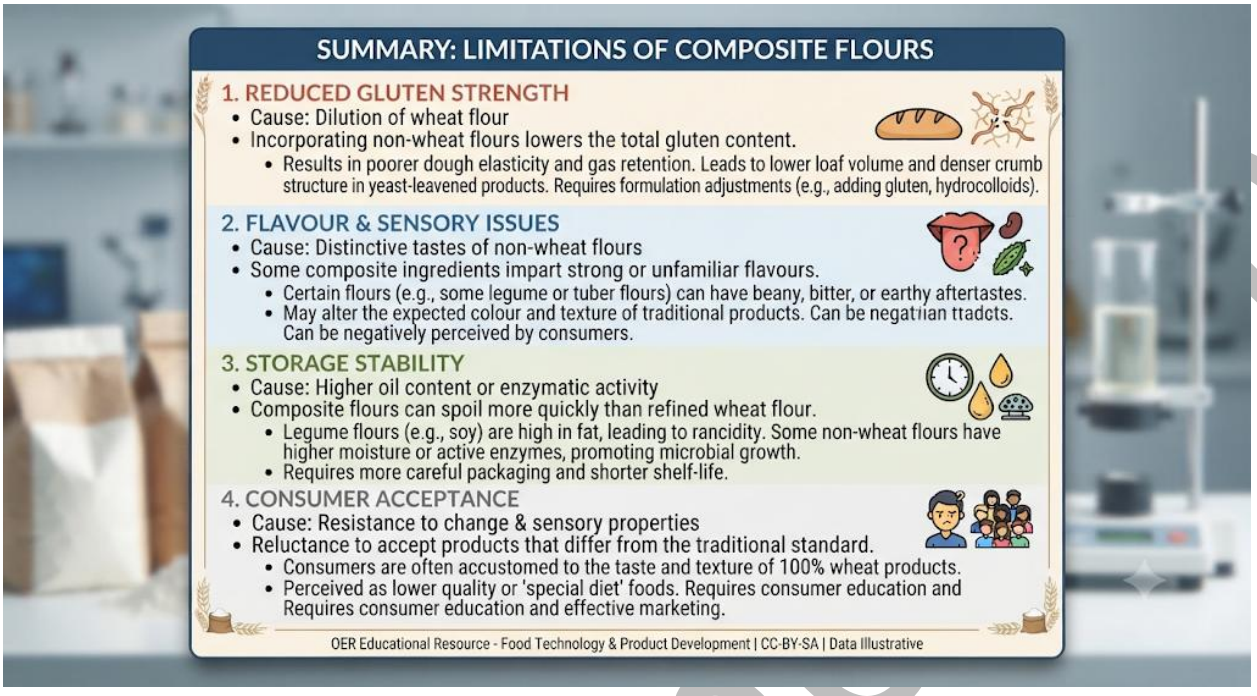

Box 4.1 Limitations of composite flours

Fill in the blank: Reduced _____ strength in composite flours can affect bread volume and texture.

**Pilot questions 4.1**

1. Define composite flours and state their importance.
2. Name two sources of flours used in composite flour blends.
3. What nutritional benefit do legume flours provide in composite flours?
4. Identify one functional advantage of composite flours.
5. Mention one limitation of using composite flours in bread making.

### 4.2 Preparation of Composite Flours

#### 4.2.1 Selection of raw materials

The preparation of **composite flours** begins with selecting suitable raw materials. Common sources include cereals (maize, sorghum, millet), tubers (cassava, yam, cocoyam), and legumes (soybean, cowpea, groundnut). Each raw material contributes unique nutritional and functional properties. For example, legumes add protein, while tubers provide starch for energy. The choice of raw materials depends on availability, cost, and intended product use.

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Image showing raw materials for composite flours (cassava roots, maize grains, soybeans)
Caption: Plate 4.1 Raw materials for composite flours

Fill in the blank: Legumes such as _____ are used in composite flours to increase protein content.

**4.2.2 Processing steps**

The processing of composite flours involves several steps:

- **Cleaning**: Removal of dirt, stones, and foreign matter.
- **Drying**: Reduction of moisture to safe levels for storage.
- **Milling**: Grinding raw materials into fine flour.
- **Blending**: Mixing wheat flour with selected non-wheat flours in specific proportions.

These steps ensure that the composite flour is safe, stable, and suitable for baking and confectionery applications.

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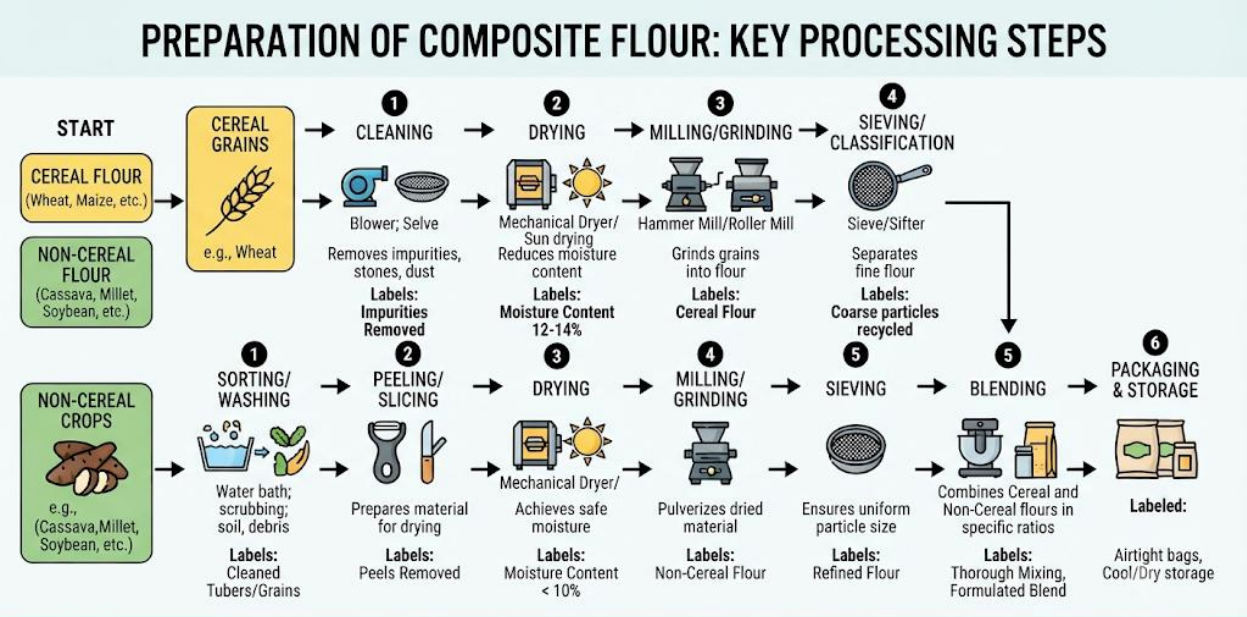


Diagram showing processing steps (cleaning, drying, milling, blending) Caption: Figure 4.2 Processing steps in composite flour preparation

Fill in the blank: The final step in composite flour preparation is _____, where flours are mixed in specific proportions.

### 4.2.3 Quality parameters in composite flour formulation

Quality parameters are critical in ensuring composite flours perform well in confectionery. These include:

- **Moisture content**: Must be low to prevent spoilage.
- **Protein content**: Determines nutritional value and dough strength.
- **Particle size**: Affects texture and baking performance.
- **Functional properties**: Such as water absorption, pasting behaviour, and gluten strength.

Monitoring these parameters ensures composite flours meet consumer expectations and regulatory standards.

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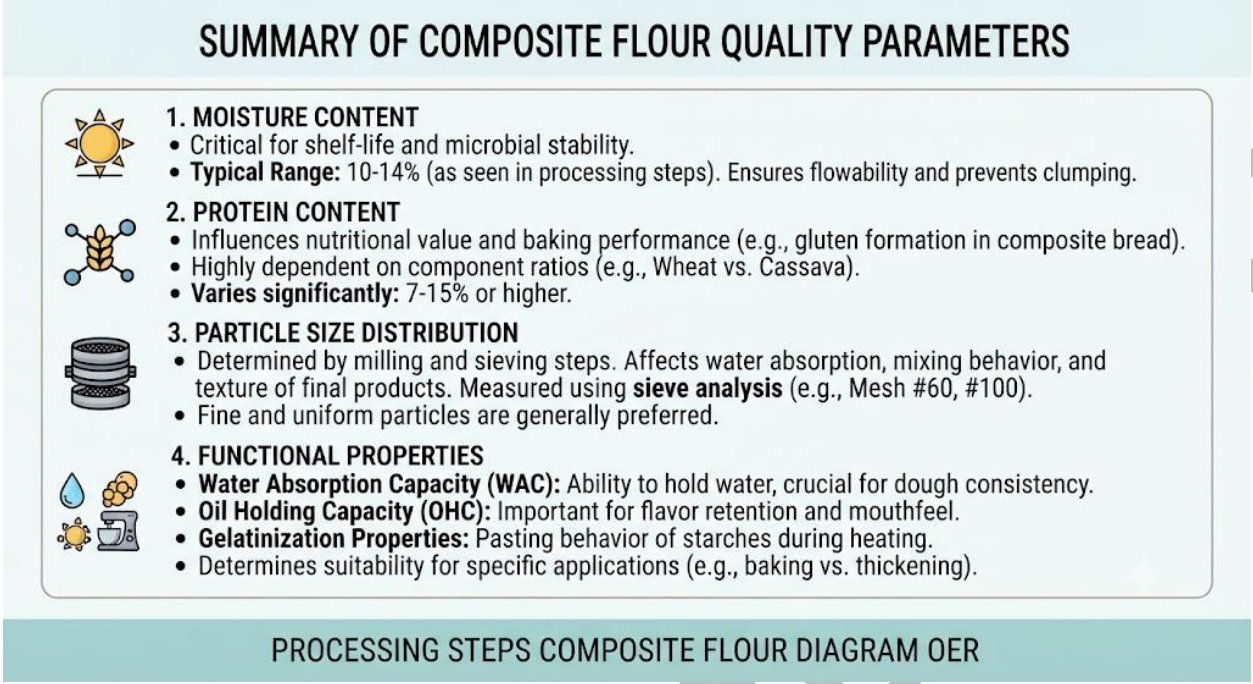


Box 4.2 Quality parameters in composite flour formulation

Fill in the blank: Low _____ content in composite flours helps to prevent spoilage during storage.

**Pilot questions 4.2**

1. Name two raw materials used in composite flour preparation.
2. What is the purpose of drying in composite flour processing?
3. List the four main steps in composite flour preparation.
4. Which quality parameter determines dough strength?
5. Why is particle size important in composite flour formulation?

### 4.3 Applications in Confectionery

#### 4.3.1 Bread and bakery products

Composite flours are widely applied in **bread and bakery products**. Wheat flour blended with cassava, maize, or sorghum flour can produce bread with reduced gluten but enhanced local crop utilisation. Legume flours such as soybean improve protein content, making bread more nutritious. While high substitution levels may affect loaf volume and texture, careful formulation ensures acceptable quality and consumer satisfaction.

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Image showing bread made with composite flours (cassava-wheat bread, sorghum-wheat bread)
Caption: Plate 4.2 Bread made with composite flours

Fill in the blank: Soybean flour in bread increases the _____ content of the product.

**4.3.2 Cakes, biscuits, and pastries**

Composite flours are also used in **cakes, biscuits, and pastries**. Cassava and yam flours provide starch that improves crispness in biscuits, while legume flours enhance protein and flavour. Maize and millet flours add colour and unique taste to cakes and pastries. These applications diversify confectionery products, making them more affordable and culturally relevant.

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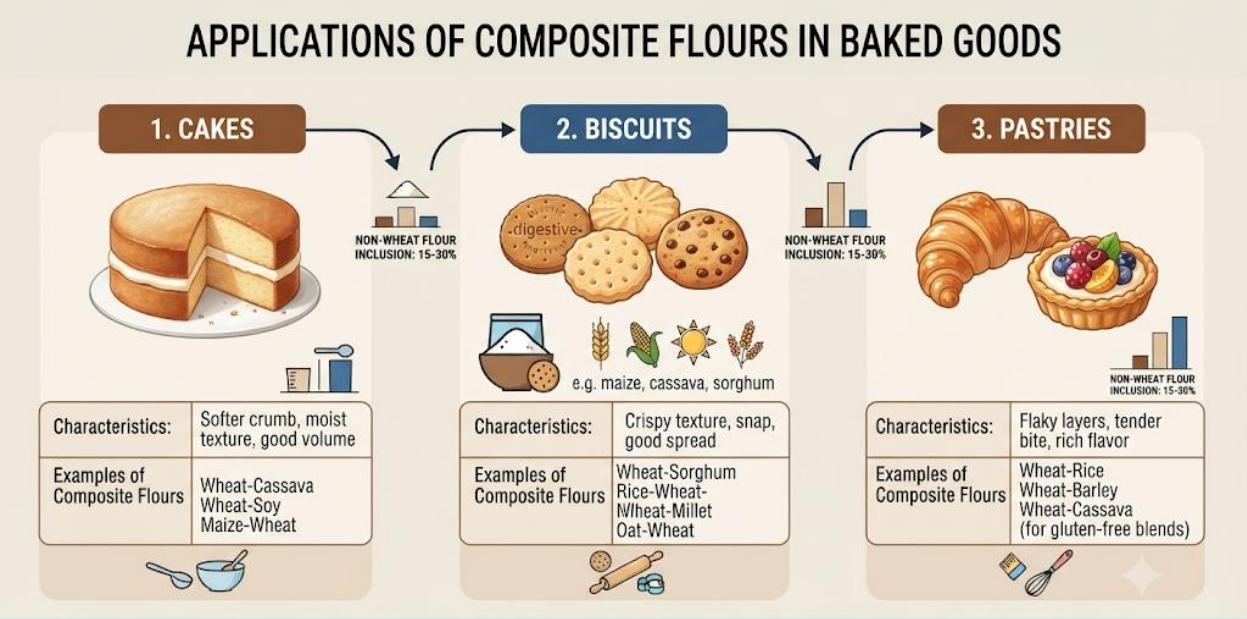


Diagram showing composite flour applications in cakes, biscuits, and pastries Caption: Figure 4.3 Composite flour applications in cakes, biscuits, and pastries

Fill in the blank: Cassava flour in biscuits improves _____ and crispness.

**4.3.3 Traditional confectionery products**

Composite flours are important in **traditional confectionery products** such as chin-chin, puff-puff, and akara. These snacks often incorporate blends of wheat with cassava, maize, or cowpea flours. The use of composite flours reduces production costs and promotes local crop utilisation. Traditional confectionery products made with composite flours are popular in many African communities and contribute to food diversity.

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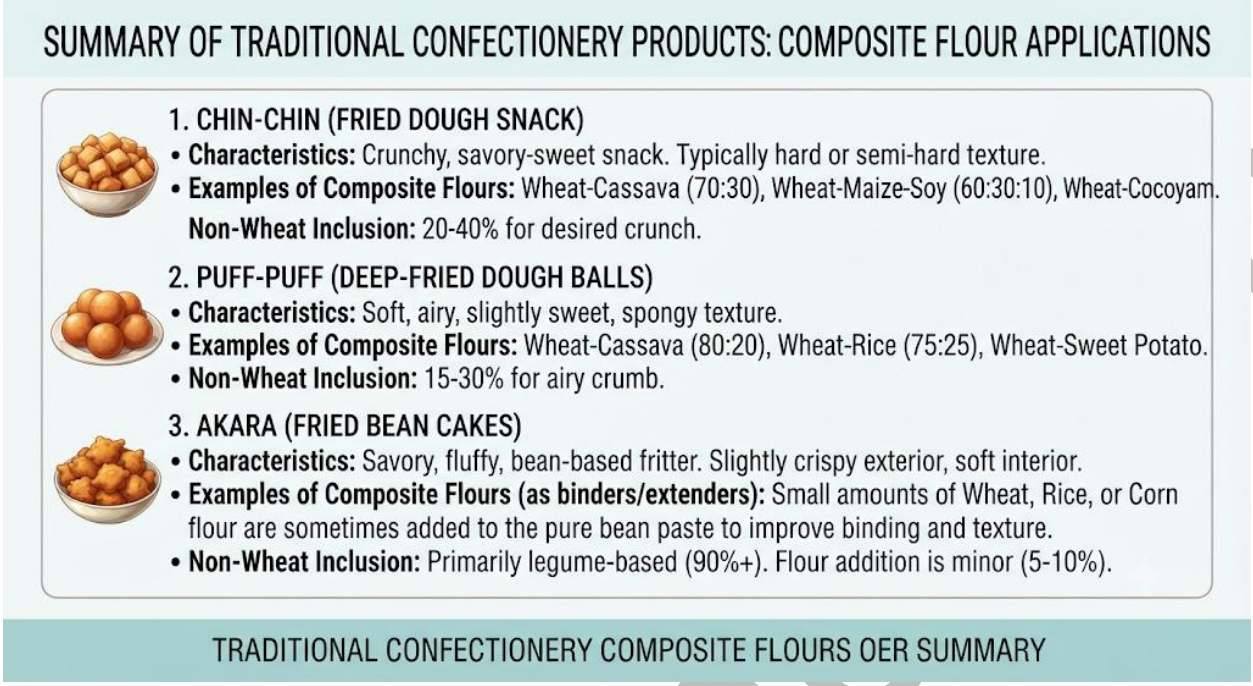


Box 4.3 Traditional confectionery products with composite flours

Fill in the blank: Puff-puff is a traditional Nigerian snack often made with wheat and _____ flour blends.

**Pilot questions 4.3**

1. Name two composite flours used in bread making.
2. What nutritional benefit does soybean flour provide in bread?
3. Which flour improves crispness in biscuits?
4. Give one example of a traditional confectionery product made with composite flours.
5. Why are composite flours important in confectionery production?

### 4.4 Quality Control and Standards

#### 4.4.1 Nutritional evaluation

Composite flours must undergo **nutritional evaluation** to ensure they meet dietary requirements. Protein, fibre, vitamins, and minerals are analysed to confirm improvements over pure wheat flour. Legume blends often enhance protein, while tuber flours contribute energy-rich starch. Nutritional evaluation ensures that products made with composite flours provide balanced diets and meet consumer expectations.

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## NUTRITIONAL EVALUATION PARAMETERS FOR COMPOSITE FLOURS

| PARAMETER | DEFINITION / IMPORTANCE | KEY DETERMINATION METHODS | TYPICAL COMPOSITE FLOUR SOURCES (Non-Wheat) |
|---|---|---|---|
| PROTEIN CONTENT | Essential for growth, tissue repair, and body functions. Composite flours can enhance amino acid balance. | Kjeldahl Method (AOAC 920.87), Dumas Combustion Method. | Soybean Flour, Peanut Flour, Cowpea Flour, Spirulina Powder. |
| DIETARY FIBRE | Crucial for digestive health, blood sugar control, and satiety. Often increased with non-wheat sources. | Enzymatic-Gravimetric Method (AOAC 991.43), Prosky Method. | Cassava Peel Flour, Millet Flour, Rice Bran, Oat Flour. |
| VITAMINS | Micronutrients vital for various metabolic processes. (e.g., Vitamin A, B-complex, C). | High-Performance Liquid Chromatography (HPLC), Spectrophotometry, Microbiological Assays. | Carrot Powder (Vitamin A), Orange-Fleshed Sweet Potato Flour, Moringa Leaf Powder |
| MINERALS | Essential for bone health, enzyme function, and oxygen transport. (e.g., Iron, Zinc, Calcium) | Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). | Malted Sorghum Flour (Iron, Zinc), Baobab Fruit Powder (Calcium, Magnesium) |

**Source:** Adapted from various OER food science textbooks, CC BY-SA 4.0

Nutritional evaluation parameters in composite flours Caption: Table 4.2 Nutritional evaluation parameters in composite flours

Fill in the blank: Legume flours in composite blends enhance the _____ content of products.

### 4.4.2 Sensory properties and consumer acceptance

**Sensory properties** such as taste, colour, aroma, and texture are critical in determining consumer acceptance of composite flour products. While nutritional value is important, consumers will only adopt products that are palatable and appealing. Sensory evaluation panels are often used to test bread, cakes, and biscuits made with composite flours. Adjusting blending ratios helps balance nutrition with desirable sensory qualities.

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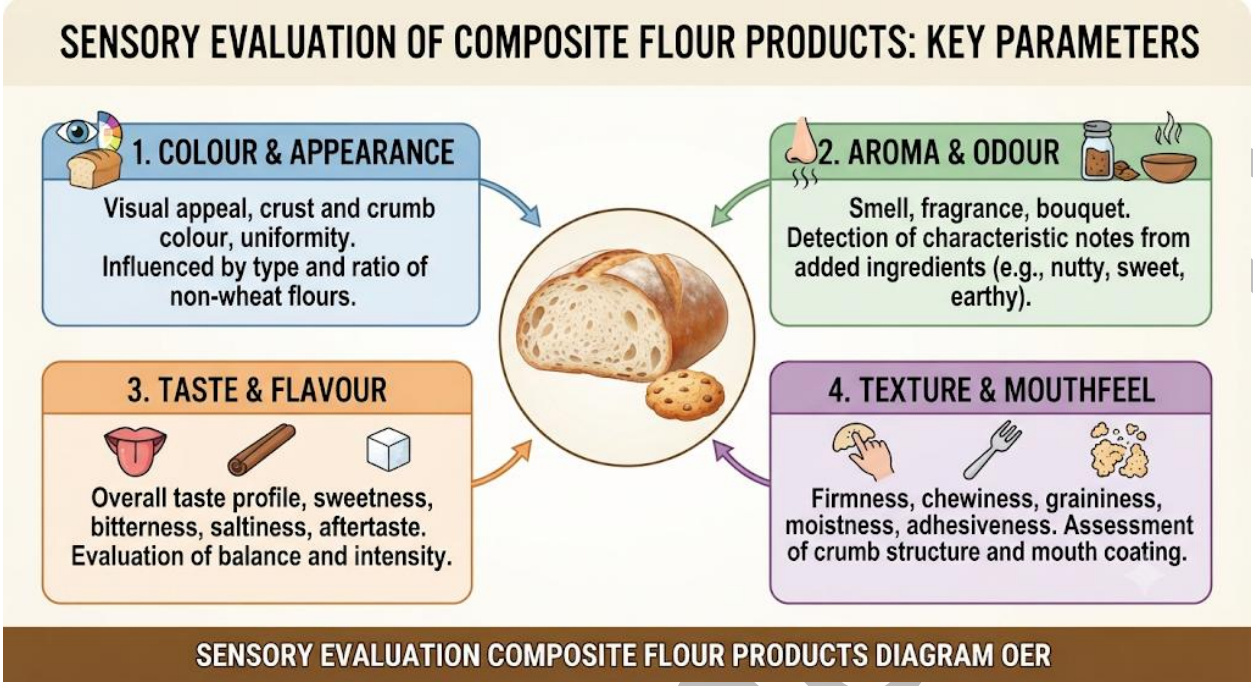


Diagram showing sensory evaluation parameters (taste, colour, aroma, texture) Caption: Figure 4.4 Sensory evaluation of composite flour products

Fill in the blank: Sensory evaluation helps determine consumer _____ of composite flour products.

**4.4.3 Regulatory and safety standards**

Composite flours and confectionery must comply with **regulatory and safety standards**. These include limits on moisture content, absence of contaminants, and adherence to food labelling laws. National and international agencies such as NAFDAC (Nigeria) and Codex Alimentarius provide guidelines for composite flour production. Compliance ensures consumer safety, supports trade, and builds trust in composite flour products.

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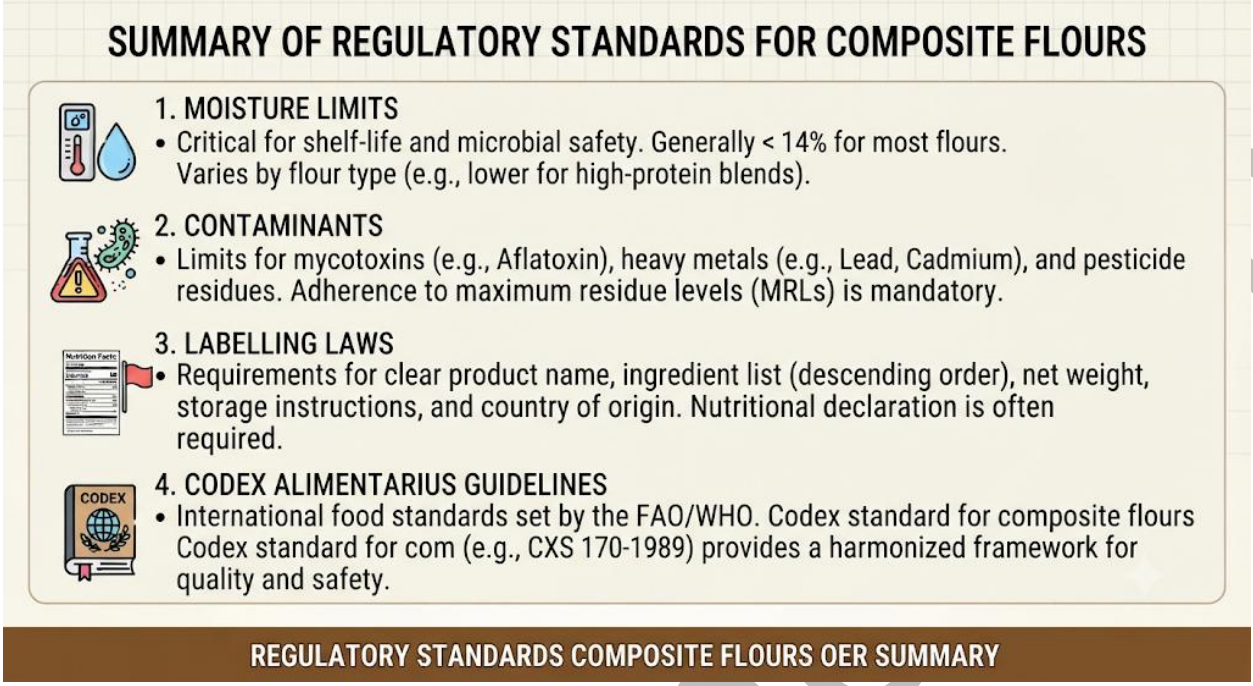


Box 4.4 Regulatory and safety standards for composite flours

Fill in the blank: Compliance with _____ standards ensures consumer safety and supports trade.

**Pilot questions 4.4**

1. What is the purpose of nutritional evaluation in composite flours?
2. Name two sensory properties tested in composite flour products.
3. Why is consumer acceptance important in confectionery production?
4. Which organisation in Nigeria regulates composite flour products?
5. How do regulatory standards support international trade?

**Series Summary**

This Series has examined the role of **composite flours and confectionery** in food technology. We began with the **principles of composite flours**, defining them, highlighting their importance, nutritional and functional advantages, and limitations. We then explored the **preparation of composite flours**, including raw material selection, processing steps, and quality parameters. Following that, we studied their **applications in confectionery**, covering bread, cakes, biscuits, pastries, and traditional products. Finally, we considered **quality control and standards**, focusing on nutritional evaluation, sensory properties, consumer acceptance, and regulatory requirements.

By connecting these discussions to the Series Learning Outcomes, you should now be able to explain the principles of composite flours, describe their preparation, outline their applications in

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confectionery, and evaluate quality control measures. This knowledge provides a foundation for developing innovative, nutritious, and culturally relevant flour-based products.

**Glossary of Terms**

- **Composite flour**: A blend of wheat flour with flours from tubers, legumes, or cereals.
- **Confectionery**: Sweet and baked goods such as bread, cakes, biscuits, and pastries.
- **Fumigation**: A chemical method used to control pests in stored flour.
- **Gluten strength**: The ability of wheat proteins to form elastic dough, affecting bread volume.
- **Hermetic storage**: Airtight storage that prevents insect infestation without chemicals.
- **Nutritional evaluation**: Analysis of protein, fibre, vitamins, and minerals in composite flours.
- **Sensory evaluation**: Testing of taste, colour, aroma, and texture to determine consumer acceptance.
- **Soybean flour**: A legume flour used to increase protein content in composite blends.
- **Traditional confectionery**: Local snacks such as chin-chin, puff-puff, and akara made with flour blends.
- **Quality parameters**: Standards such as moisture content, particle size, and functional properties that determine flour performance.

**Concept Check Questions [Series 4]**

**Objective questions**

1. Composite flours are blends of wheat flour with flours from _____, legumes, and cereals. (Linked to SLO 4.1)
2. Which legume flour is commonly used to increase protein content in bread? (Linked to SLO 4.3)
3. Sensory evaluation helps determine consumer _____ of composite flour products. (Linked to SLO 4.4)

**Short-answer questions**

4. List two raw materials used in composite flour preparation. (Linked to SLO 4.2)
5. State one limitation of composite flours in bread making. (Linked to SLO 4.1)

**Long-answer questions**

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6. Describe the processing steps in composite flour preparation and explain their importance. (Linked to SLO 4.2)
    - *Basic response*: Learners should mention cleaning, drying, milling, and blending.
    - *Value-added response*: Outstanding learners may discuss how each step ensures safety, stability, and product quality.
7. Evaluate the importance of quality control in composite flour and confectionery production, considering nutrition, sensory properties, and regulatory standards. (Linked to SLO 4.4)
    - *Basic response*: Learners should mention nutritional evaluation, sensory testing, and compliance with standards.
    - *Value-added response*: Outstanding learners may connect these practices to consumer trust, market competitiveness, and international trade.

**Answers to Concept Check Questions [Series 4]**

1. Tubers
2. Soybean flour
3. Acceptance
4. Cassava, maize
5. Reduced gluten strength affecting bread volume and texture
6. *Basic*: Cleaning removes impurities, drying reduces moisture, milling produces fine flour, blending creates the composite mix. *Value-added*: Each step ensures safety, prevents spoilage, and produces flour suitable for confectionery applications.
7. *Basic*: Quality control ensures nutrition, sensory appeal, and compliance with standards. *Value-added*: It builds consumer confidence, supports competitiveness, and aligns with international regulations.

**Answers to Pilot Questions [Series 4]**

**Part 4.1**

1. Blends of wheat with tubers, legumes, cereals; reduce wheat dependence
2. Tubers, legumes
3. Protein
4. Improved dough handling
5. Reduced gluten strength

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**Part 4.2**

1. Cassava, sorghum
2. To reduce moisture and prevent spoilage
3. Cleaning, drying, milling, blending
4. Protein content
5. Affects texture and baking performance

**Part 4.3**

1. Cassava flour, sorghum flour
2. Protein enrichment
3. Cassava flour
4. Chin-chin
5. They diversify products and reduce costs

**Part 4.4**

1. To ensure dietary adequacy and product quality
2. Taste, texture
3. Because consumers adopt only palatable products
4. NAFDAC
5. By ensuring compliance with international food safety laws

**References and Attributions [Series 4]**

- Figures, plates, tables, and boxes were suggested as placeholders with AI prompts for generation. For example: “Create a labelled diagram showing sensory evaluation parameters: taste, colour, aroma, texture” (Figure 4.4).
- Suggested open educational resource (OER) search strings included: “sources of composite flours diagram OER”, “processing steps composite flour diagram OER”, “bread composite flours cassava sorghum OER image”, “regulatory standards composite flours OER summary”.
- AI-generated placeholders were designed to illustrate concepts such as raw materials, processing steps, applications in confectionery, and quality control practices.
- Attribution: Content developed from course outline provided in FST 501: Cereals and Tubers Technology.

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# Series 5: Processing and Enrichment Technologies

**Series outline**

- **5.1 Principles of Processing**
    - 5.1.1 Definition and importance of processing
    - 5.1.2 Traditional vs. modern processing methods
    - 5.1.3 Impact of processing on nutritional quality
- **5.2 Primary Processing Techniques**
    - 5.2.1 Cleaning and grading
    - 5.2.2 Milling and grinding
    - 5.2.3 Fermentation and germination
- **5.3 Secondary Processing and Product Development**
    - 5.3.1 Extrusion and baking
    - 5.3.2 Fortified cereal and tuber products
    - 5.3.3 Novel product innovations
- **5.4 Enrichment and Fortification Technologies**
    - 5.4.1 Nutrient enrichment strategies (protein, vitamins, minerals)
    - 5.4.2 Fortification methods (premixes, coatings, biofortification)
    - 5.4.3 Case studies of enriched cereal and tuber products
- **5.5 Quality Assurance and Standards**
    - 5.5.1 Nutritional evaluation of processed products
    - 5.5.2 Safety and hygiene in processing plants
    - 5.5.3 Regulatory frameworks and international standards

**Introduction**

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Processing and enrichment technologies are central to transforming cereals and tubers into safe, nutritious, and market-ready products. Processing involves primary and secondary techniques that convert raw crops into usable forms, while enrichment and fortification enhance their nutritional value to meet dietary needs. These technologies not only improve food quality but also support food security, reduce post-harvest losses, and create diverse products for consumers.

The aim of this Series is to provide you with knowledge of the principles, techniques, and standards involved in processing and enrichment of cereals and tubers, and to enable you to evaluate their impact on nutrition, safety, and product development.

We shall commence this Series by examining the **principles of processing**, focusing on definitions, importance, and nutritional impacts. Next, we will explore **primary processing techniques**, including cleaning, milling, and fermentation. Following that, we will study **secondary processing and product development**, covering extrusion, baking, and novel innovations. We will then move on to **enrichment and fortification technologies**, highlighting strategies, methods, and case studies. Finally, we will conclude with **quality assurance and standards**, emphasising nutritional evaluation, safety, hygiene, and regulatory frameworks.

**Series Learning Outcomes**

Upon completing this Series, you should be able to:

- **SLO 5.1** explain the principles of processing and their impact on nutritional quality,
- **SLO 5.2** describe primary processing techniques for cereals and tubers,
- **SLO 5.3** outline secondary processing methods and product development innovations,
- **SLO 5.4** differentiate enrichment and fortification technologies and evaluate their applications,
- **SLO 5.5** assess quality assurance practices and regulatory standards in processing and enrichment.

## 5.1 Principles of Processing

### 5.1.1 Definition and importance of processing

**Processing** refers to the transformation of raw cereals and tubers into forms that are safe, nutritious, and convenient for consumption or further use. It is important because it reduces post-harvest losses, enhances shelf life, improves palatability, and creates diverse food products. Processing also supports food security and economic development by adding value to agricultural produce.

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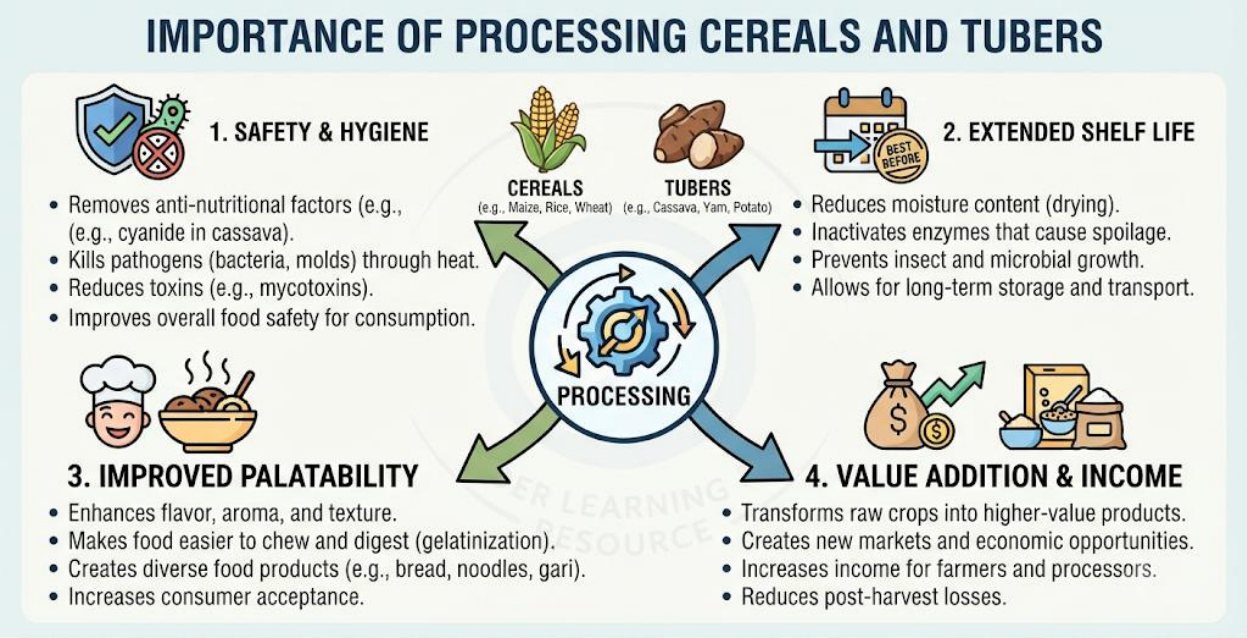


importance of processing cereals tubers diagram OER

Diagram showing importance of processing (safety, shelf life, palatability, value addition) Caption: Figure 5.1 Importance of processing cereals and tubers

Fill in the blank: Processing helps to reduce post-harvest _____ and improve food safety.

**5.1.2 Traditional vs. modern processing methods**

Processing methods can be classified into **traditional** and **modern** approaches.

- Traditional methods include pounding, sun-drying, and fermentation, which are simple and widely used in rural communities.
- Modern methods involve mechanised milling, extrusion, and controlled fermentation, which improve efficiency, consistency, and product quality.

While traditional methods are cost-effective and culturally relevant, modern methods ensure large-scale production and compliance with safety standards.

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**COMPARISON OF TRADITIONAL VS. MODERN PROCESSING METHODS FOR CEREALS AND TUBERS**

| COMPARISON CRITERIA | TRADITIONAL METHODS | MODERN METHODS |
|---|---|---|
| EXAMPLES | Sun drying of maize, cassava chips; Pounding of yam; Fermentation of cereals (ogi, burukutu). | Mechanical oven drying of cassava; Hammer milling of maize; Extrusion cooking of cereals (breakfast cereals); Spray drying. |
| SCALE OF PRODUCTION | Small-scale, household or community level. | Large-scale, industrial, factory level. |
| EQUIPMENT & TECHNOLOGY | Manual tools, simple implements (mortar, pestle, hand grater, sun drying). | Automated machinery, sophisticated technology (mechanical dryers, roller mills, extruders). |
| EFFICIENCY & TIME | Labor-intensive, time-consuming, lower output. | Less labor-intensive, fast, high-volume output. |
| QUALITY CONSISTENCY | Variable product quality, depends on skill and environment. | Consistent product quality, standardized processes. |
| SAFETY & HYGIENE | Risk of contamination from dust, insects, animals; limited hygiene control. | Strict hygiene control, controlled environment, reduced contamination risk. |
| NUTRIENT RETENTION | Often better retention of certain heat-sensitive nutrients (e.g., some vitamins in sun-drying). | Nutrient loss possible due to high heat, but can also be fortified. |
| COST & ACCESSIBILITY | Low initial cost, accessible to rural farmers, but labor costs are high. | High initial investment in equipment, requires infrastructure. |

TRADITIONAL VS MODERN PROCESSING CEREALS TUBERS OER TABLE

Comparison of traditional and modern processing methods Caption: Table 5.1 Traditional vs. modern processing methods

Fill in the blank: Modern processing methods improve efficiency and ensure compliance with _____ standards.

### 5.1.3 Impact of processing on nutritional quality

Processing has both positive and negative impacts on **nutritional quality**.

- Positive impacts: Fermentation enhances protein digestibility and reduces anti-nutritional factors. Germination increases vitamin content. Fortification adds essential nutrients.
- Negative impacts: Excessive milling may remove fibre and micronutrients, while high-heat treatments can degrade vitamins.

Balancing processing techniques is essential to maximise nutritional benefits while minimising losses.

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**SUMMARY OF POSITIVE AND NEGATIVE IMPACTS OF PROCESSING ON NUTRITIONAL QUALITY**

| POSITIVE IMPACTS | NEGATIVE IMPACTS |
|---|---|
| ENHANCED BIOAVAILABILITY: Processing (e.g., fermentation, milling) can break down complex food matrices, making nutrients like iron, zinc, and beta-carotene easier to absorb. | NUTRIENT LOSSES: High heat, prolonged cooking, and leaching during boiling can destroy heat-sensitive vitamins (e.g., Vitamin C, B vitamins) and minerals. |
| INCREASED DIGESTIBILITY: Cooking (e.g., gelatinization of starch, denaturation of protein) improves the digestibility of cereals and tubers. | FIBER LOSS: Refinement processes (e.g., milling cereals to white flour) remove the bran and germ, resulting in a significant loss of dietary fiber. |
| REDUCTION OF ANTI-NUTRIENTS: Techniques like soaking, germination, and fermentation reduce anti-nutritional factors (e.g., phytates, tannins, cyanogenic glycosides) that inhibit nutrient absorption. | FORMATION OF HARMFUL COMPOUNDS: Excessive heat (e.g., frying, roasting at very high temperatures) can lead to the formation of acrylamide, advanced glycation end-products (AGEs), and other potentially harmful substances. |
| IMPROVED SHELF LIFE & SAFETY: Processing methods like drying and canning extend shelf life and eliminate pathogens, reducing foodborne illness risks. | REDUCED PROTEIN QUALITY: Severe heat treatment can damage amino acids (e.g., lysine), reducing the overall protein quality and bioavailability. |
| FORTIFICATION OPPORTUNITIES: Processing allows for the addition of essential micronutrients to staple foods (e.g., flour fortification) to combat deficiencies. | OXIDATION: Exposure to air, light, and heat during processing can cause the oxidation of fats and fat-soluble vitamins (e.g., Vitamin E), leading to rancidity and nutrient degradation. |

IMPACT OF PROCESSING ON NUTRITIONAL QUALITY CEREALS TUBERS OER SUMMARY

Box 5.1 Impact of processing on nutritional quality

Fill in the blank: Fermentation enhances protein digestibility and reduces _____ factors in cereals and tubers.

**Pilot questions 5.1**

1. Define processing in the context of cereals and tubers.
2. Name two benefits of processing agricultural produce.
3. Give one example each of traditional and modern processing methods.
4. What is one positive impact of fermentation on nutritional quality?
5. Mention one limitation of excessive milling.

**5.2 Primary Processing Techniques**

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### 5.2.1 Cleaning and grading

**Cleaning and grading** are the first steps in primary processing. Cleaning removes foreign matter such as stones, dust, and husks, while grading sorts cereals and tubers based on size, weight, or quality. These steps ensure safety, improve efficiency in later processing, and enhance product uniformity.

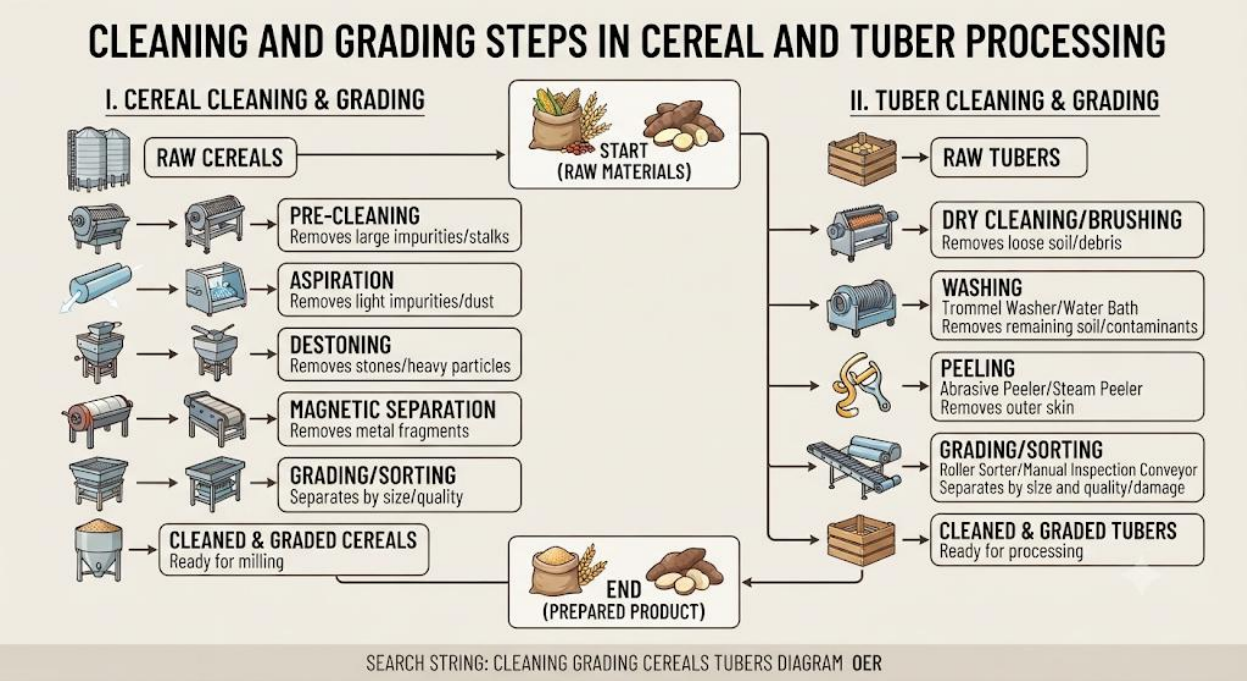


Diagram showing cleaning and grading steps (removal of impurities, sorting by size/quality)
Caption: Figure 5.2 Cleaning and grading in primary processing

Fill in the blank: Cleaning removes foreign matter such as stones, dust, and _____ from cereals and tubers.

### 5.2.2 Milling and grinding

**Milling and grinding** convert cereals and tubers into flour or meal. Milling involves breaking down grains into fine particles, while grinding reduces tubers into flour or starch. These processes improve digestibility, expand product applications, and form the basis for bread, biscuits, and other confectionery. Modern milling ensures uniform particle size and better control of nutritional quality.

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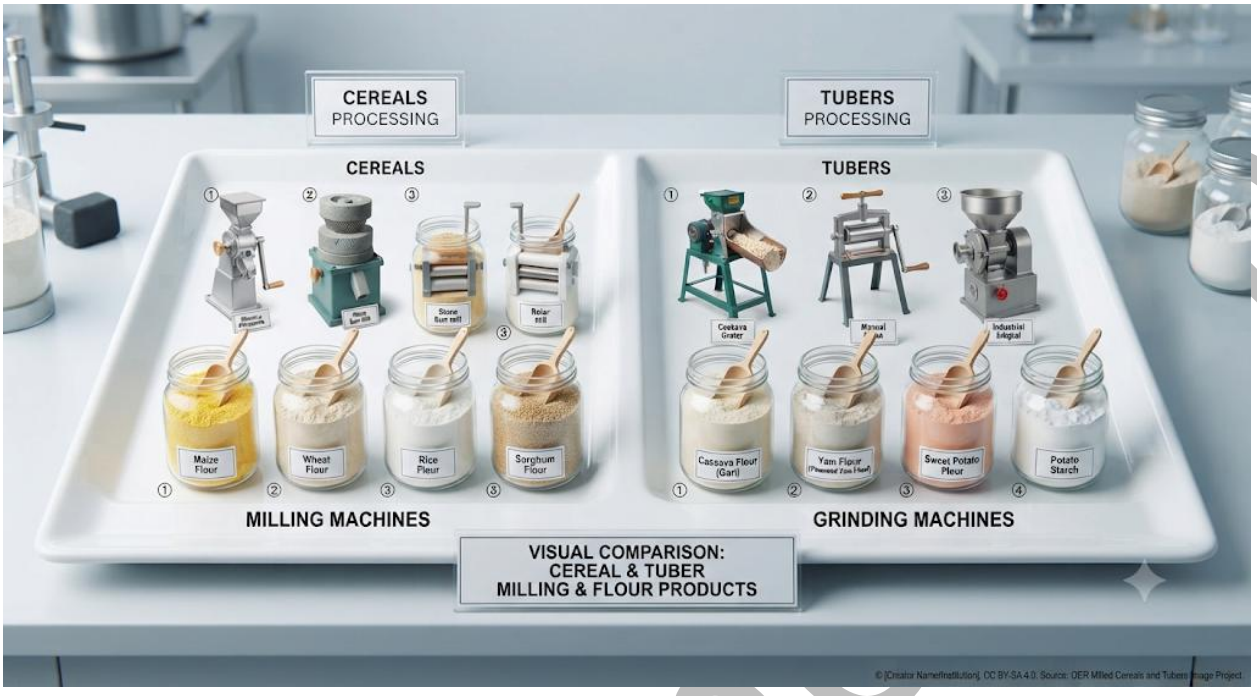


Image showing milling machines and ground flour products Caption: Plate 5.1 Milling and grinding of cereals and tubers

Fill in the blank: Milling improves digestibility and provides flour for _____ products.

**5.2.3 Fermentation and germination**

**Fermentation and germination** are biological processing techniques.

- Fermentation uses microorganisms to break down carbohydrates, producing products like ogi (fermented maize porridge) and gari (fermented cassava). It enhances flavour, reduces anti-nutritional factors, and improves protein digestibility.
- Germination involves sprouting grains, which increases vitamin content (especially B-vitamins) and improves bioavailability of minerals.

These techniques are traditional yet highly valuable for nutritional enrichment.

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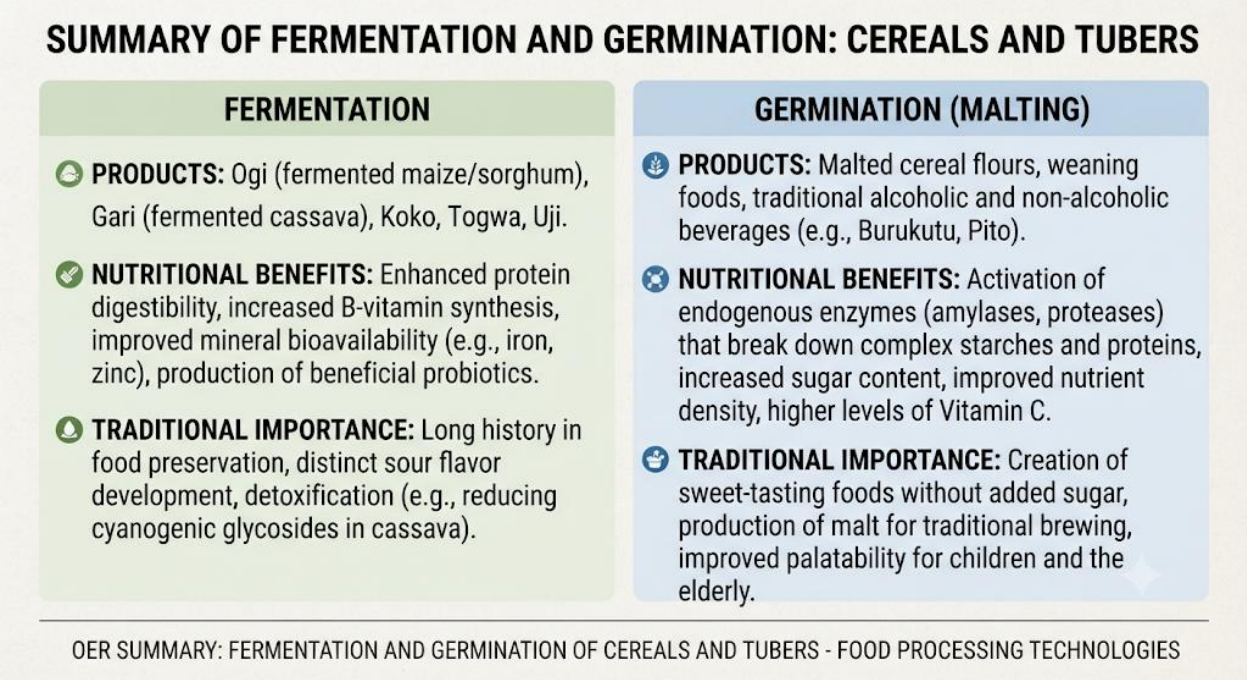


Box 5.2 Fermentation and germination in primary processing

Fill in the blank: Germination increases vitamin content, especially _____ vitamins, in cereals.

**Pilot questions 5.2**

1. What is the purpose of cleaning and grading in primary processing?
2. Name one product obtained from milling cereals.
3. How does milling improve digestibility?
4. Give one example of a fermented cereal product.
5. What nutritional benefit does germination provide?

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### 5.3 Secondary Processing and Product Development

#### 5.3.1 Extrusion and baking

**Extrusion and baking** are key secondary processing methods.

- **Extrusion** involves forcing cereal or tuber flours through a machine under heat and pressure to produce snacks, breakfast cereals, and instant foods. It improves digestibility and allows fortification with nutrients.
- **Baking** transforms flour into bread, cakes, and biscuits. Composite flours can be used here to diversify products and reduce reliance on wheat.

These methods create value-added products that are convenient and widely accepted.

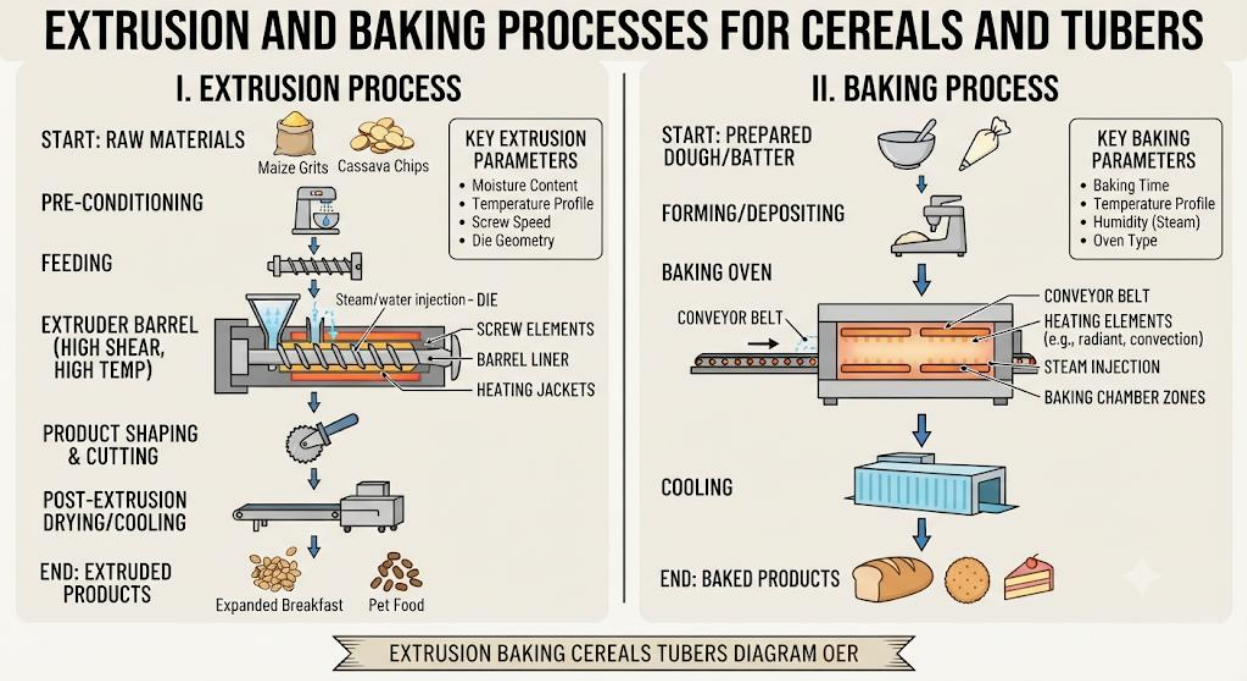


Diagram showing extrusion and baking processes Caption: Figure 5.3 Extrusion and baking in secondary processing

Fill in the blank: Extrusion produces snacks and _____ cereals from composite flours.

### 5.3.2 Fortified cereal and tuber products

Secondary processing often includes **fortification**, where essential nutrients are added to products. Examples include vitamin-enriched cassava flour, iron-fortified maize meal, and protein-enriched biscuits. Fortification addresses nutritional deficiencies such as anaemia and protein-energy malnutrition, making processed foods more beneficial to public health.

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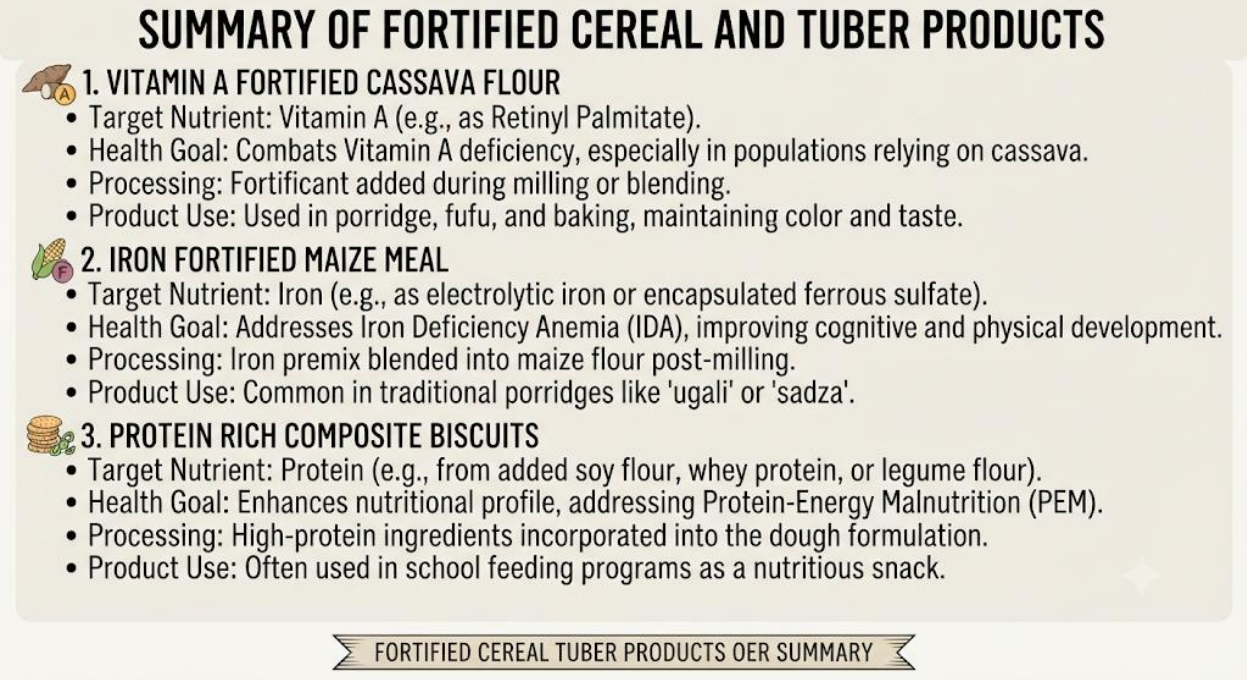


Box 5.3 Examples of fortified cereal and tuber products

Fill in the blank: Iron-fortified maize meal helps to reduce _____ deficiency in populations.

**5.3.3 Novel product innovations**

**Novel innovations** in secondary processing include instant porridges, gluten-free bakery items, and ready-to-eat tuber-based snacks. Advances in technology allow blending of composite flours with functional ingredients such as probiotics or fibre enhancers. These innovations respond to consumer demand for healthier, convenient, and diverse food options.

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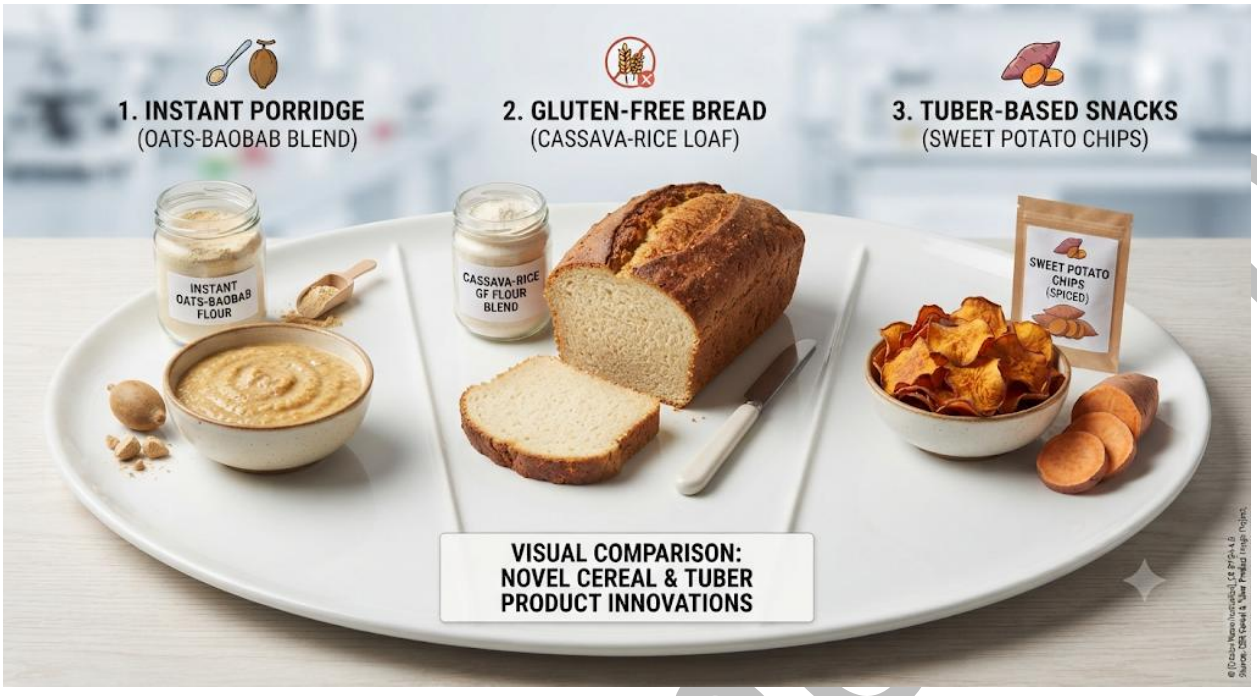


Image showing novel products (instant porridge, gluten-free bread, tuber-based snacks) Caption: Plate 5.2 Novel product innovations in cereals and tubers

Fill in the blank: Gluten-free bakery items are produced to meet the needs of consumers with _____ intolerance.

**Pilot questions 5.3**

1. What is extrusion used for in cereal and tuber processing?
2. Name one product obtained through baking.
3. Give an example of a fortified cereal or tuber product.
4. What nutritional deficiency does iron fortification help to reduce?
5. Mention one novel product innovation in secondary processing.

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**5.4 Enrichment and Fortification Technologies**

**5.4.1 Nutrient enrichment strategies**

**Nutrient enrichment** involves improving the natural nutrient profile of cereals and tubers during processing. Strategies include:

- Protein enrichment using legumes such as soybeans or cowpeas.
- Vitamin enrichment through germination or fermentation, which increases B-vitamins.
- Mineral enrichment by blending with nutrient-rich crops like amaranth or moringa.

These strategies help address malnutrition and improve dietary diversity.

**NUTRIENT ENRICHMENT STRATEGIES FOR CEREALS AND TUBERS**

| | STRATEGY / ENRICHMENT AGENT | KEY NUTRIENTS TARGETED | IMPLEMENTATION METHODS & FOOD APPLICATIONS |
|---|---|---|---|
| | 1. PROTEIN FROM LEGUMES | Essential Amino Acids, Lysine, Total Protein Content | Blend legume flours (e.g., soy, cowpea, peanut) with cereal flours (e.g., maize, cassava) to form composite flours. \| Use in porridges, breads, biscuits, and complementary foods. |
| | 2. VITAMINS FROM GERMINATION (MALTING) | B-Vitamins (Thiamine, Riboflavin, Niacin), Vitamin C, Pro-Vitamin A (in biofortified varieties) | Soak and germinate cereal or tuber grains under controlled conditions. The process activates endogenous enzymes, increasing nutrient bioavailability and content. \| Use malted flours in traditional beverages (e.g., Ogi, Pito), porridges, and weaning foods. |
| | 3. MINERALS FROM MORINGA LEAF POWDER | Iron, Calcium, Zinc, Magnesium | Dry and mill fresh Moringa oleifera leaves into a fine, nutrient-dense powder. Incorporate the powder into food formulations. \| Add to porridges, stews, soups, and baked goods (at levels of 2-5% to avoid flavor chage). |

**NUTRIENT ENRICHMENT CEREALS TUBERS OER TABLE**

Table showing enrichment strategies (protein, vitamins, minerals) Caption: Table 5.4 Nutrient enrichment strategies in cereals and tubers

Fill in the blank: Germination of cereals increases _____ vitamins in the grain.

**5.4.2 Fortification methods**

**Fortification** is the deliberate addition of nutrients to food products. Methods include:

- **Premixes**: Adding nutrient powders (iron, iodine, vitamins) during milling.
- **Coatings**: Applying nutrient-rich layers to grains or tubers.
- **Biofortification**: Breeding crops to naturally contain higher nutrient levels (e.g., vitamin A-rich cassava).

Fortification is widely used in public health programs to combat deficiencies.

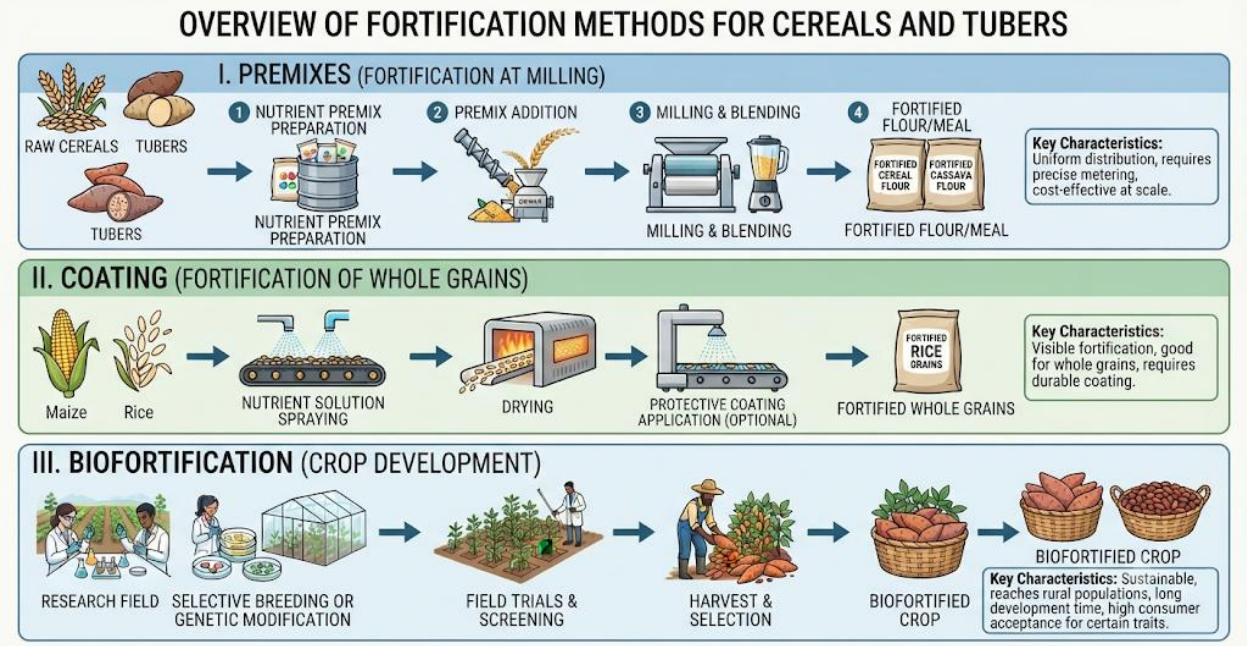


Diagram showing fortification methods (premixes, coatings, biofortification) Caption: Figure 5.4 Fortification methods in cereals and tubers

Fill in the blank: Biofortification involves breeding crops to naturally contain higher _____ levels.

### 5.4.3 Case studies of enriched cereal and tuber products

Several **case studies** illustrate successful enrichment and fortification:

- **Iron-fortified maize meal** in Southern Africa to reduce anaemia.
- **Vitamin A cassava** developed through biofortification to combat vitamin A deficiency.
- **Protein-enriched biscuits** using soybean flour to improve child nutrition.

These examples show how enrichment technologies can be applied to solve real nutritional challenges.

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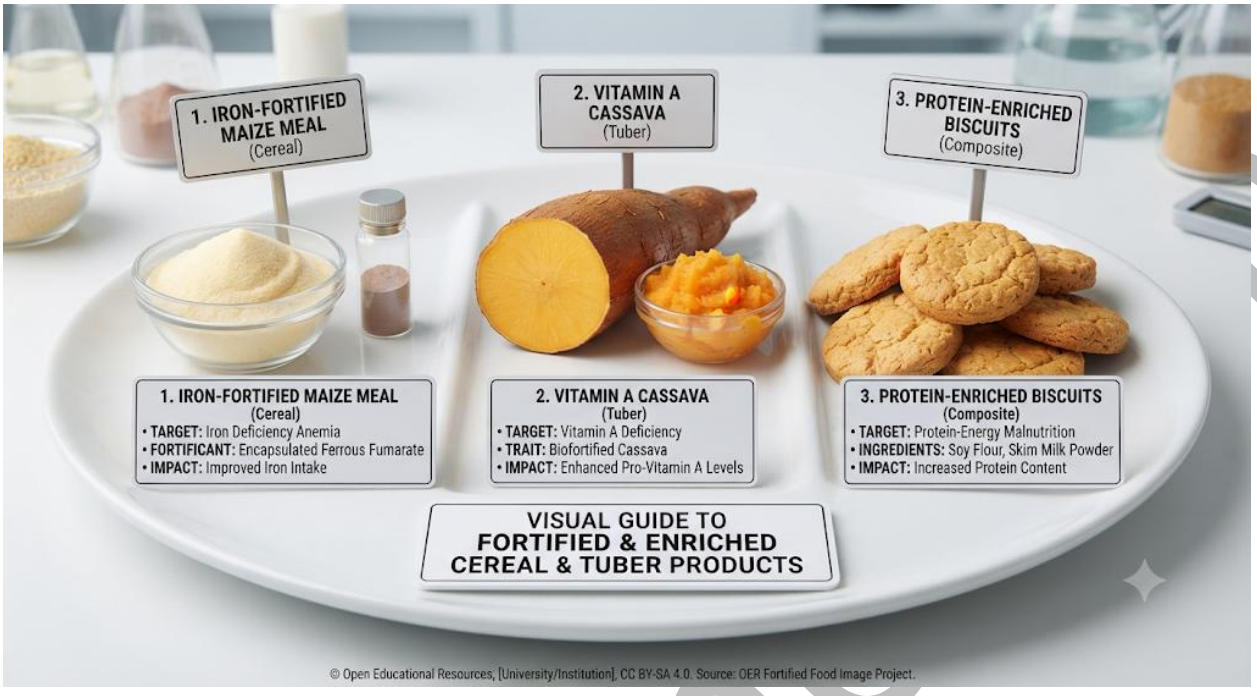

Image showing fortified products (iron maize meal, vitamin A cassava, protein biscuits) Caption: Plate 5.3 Case studies of enriched cereal and tuber products

Fill in the blank: Vitamin A cassava was developed to combat _____ deficiency in populations.

**Pilot questions 5.4**

1. What is the purpose of nutrient enrichment in cereals and tubers?
2. Name one strategy used for protein enrichment.
3. List two fortification methods.
4. Give one example of a biofortified crop.
5. Why are case studies important in understanding enrichment technologies?

**5.5 Quality Assurance and Standards**

**5.5.1 Nutritional evaluation of processed products**

Processed cereals and tubers must undergo **nutritional evaluation** to ensure enrichment and fortification goals are achieved. Parameters include protein, fibre, vitamins, minerals, and energy content. Evaluations confirm that products meet dietary requirements and help identify nutrient losses during processing.

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## NUTRITIONAL EVALUATION PARAMETERS FOR PROCESSED CEREALS AND TUBERS

| PARAMETER | KEY COMPONENTS / MEASUREMENT | IMPORTANCE | METHODS OF ANALYSIS | IMPACT OF PROCESSING |
|---|---|---|---|---|
| 1. PROTEIN CONTENT | Total Nitrogen (Kjeldahl method), Amino Acid Profile | Muscle building, enzyme function, hormone synthesis. Essential for growth and repair. | Kjeldahl or Dumas method (Nitrogen-to-Protein conversion), HPLC for Amino Acids | Can be denatured by heat, but concentration can increase with milling (removal of bran/germ) or decrease (leaching). |
| 2. DIETARY FIBRE | Soluble Fibre, Insoluble Fibre, Total Dietary Fibre | Digestive health, blood sugar control, satiety, cholesterol reduction. | Enzymatic-gravimetric method (AOAC 985.29) | Significantly reduced by refining (milling cereals to white flour), removed in tuber peeling. |
| 3. VITAMINS | Water-soluble (B complex, C) and Fat-soluble (A, D, E, K) | Metabolic regulation, immune function, antioxidant activity. | HPLC (High-Performance Liquid Chromatography), Microbiological assays | Heat-sensitive (Vitamin C, Thiamin) and light-sensitive, subject to leaching during boiling. |
| 4. MINERALS | Macro-minerals (Ca, P, K, Mg) and Micro-minerals (Fe, Zn, Cu, Mn) | Bone health, oxygen transport (Iron), electrolyte balance. | Atomic Absorption Spectroscopy (AAS), ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry) | Relatively heat stable, but can be lost through leaching and removal of bran/germ. Bioavailability can be affected by anti-nutrients. |
| 5. ENERGY VALUE (CALORIES) | Total Metabolizable Energy, Carbohydrates, Fats, Protein | Fuel for all bodily functions, physical activity, and basal metabolic rate. | Bomb Calorimetry (Gross Energy) or calculation from Atwater factors (Fat x 9, Carb x 4, Protein x 4) | Increased by fat addition, decreased by water addition (dilution). Starch gelatinization improves digestibility. |

NUTRITIONAL EVALUATION PROCESSED CEREALS TUBERS OER TABLE

Table showing nutritional evaluation parameters (protein, fibre, vitamins, minerals, energy)
Caption: Table 5.5 Nutritional evaluation of processed products

Fill in the blank: Nutritional evaluation helps to confirm that processed products meet _____ requirements.

### 5.5.2 Safety and hygiene in processing plants

Maintaining **safety and hygiene** in processing plants is critical to prevent contamination. This includes cleaning equipment, controlling pests, ensuring worker hygiene, and monitoring storage conditions. Good manufacturing practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) systems are often applied to guarantee food safety.

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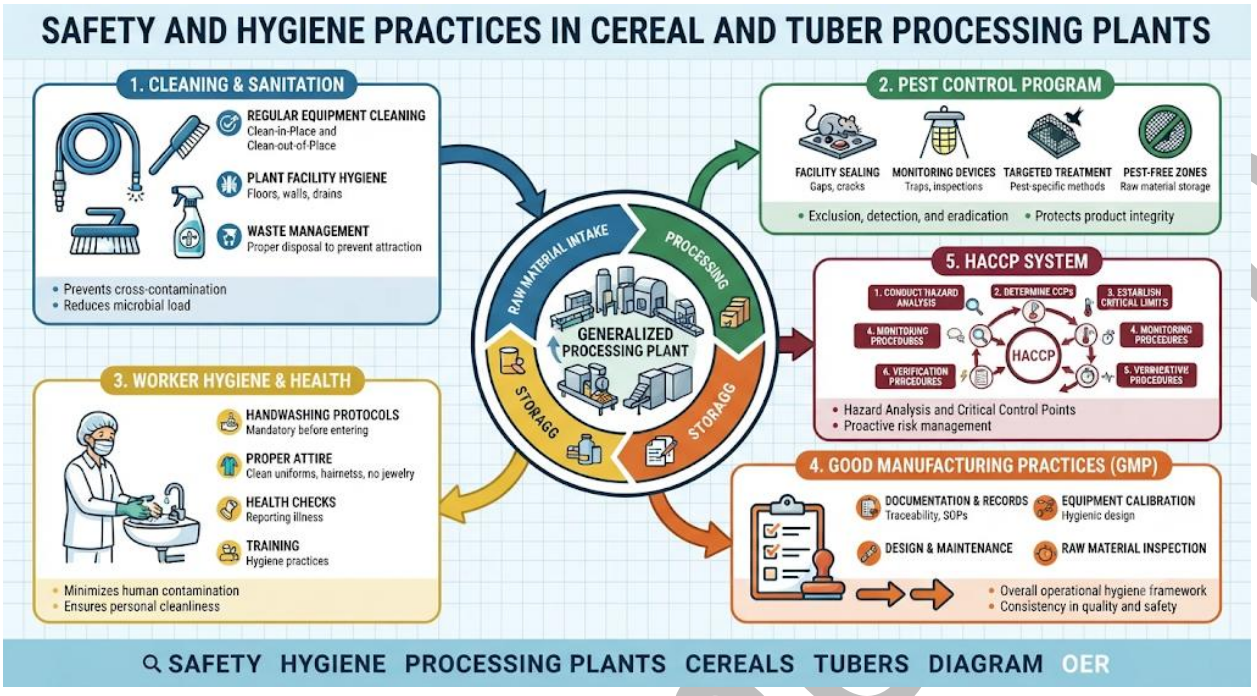


Diagram showing safety and hygiene practices in processing plants Caption: Figure 5.5 Safety and hygiene in processing plants

Fill in the blank: Good manufacturing practices (GMP) and _____ systems are applied to guarantee food safety.

### 5.5.3 Regulatory frameworks and international standards

Processed and enriched products must comply with **regulatory frameworks and international standards**. National agencies such as NAFDAC (Nigeria) and international bodies like Codex Alimentarius set guidelines for nutrient fortification, labelling, and safety. Compliance ensures consumer protection, supports trade, and builds trust in food systems.

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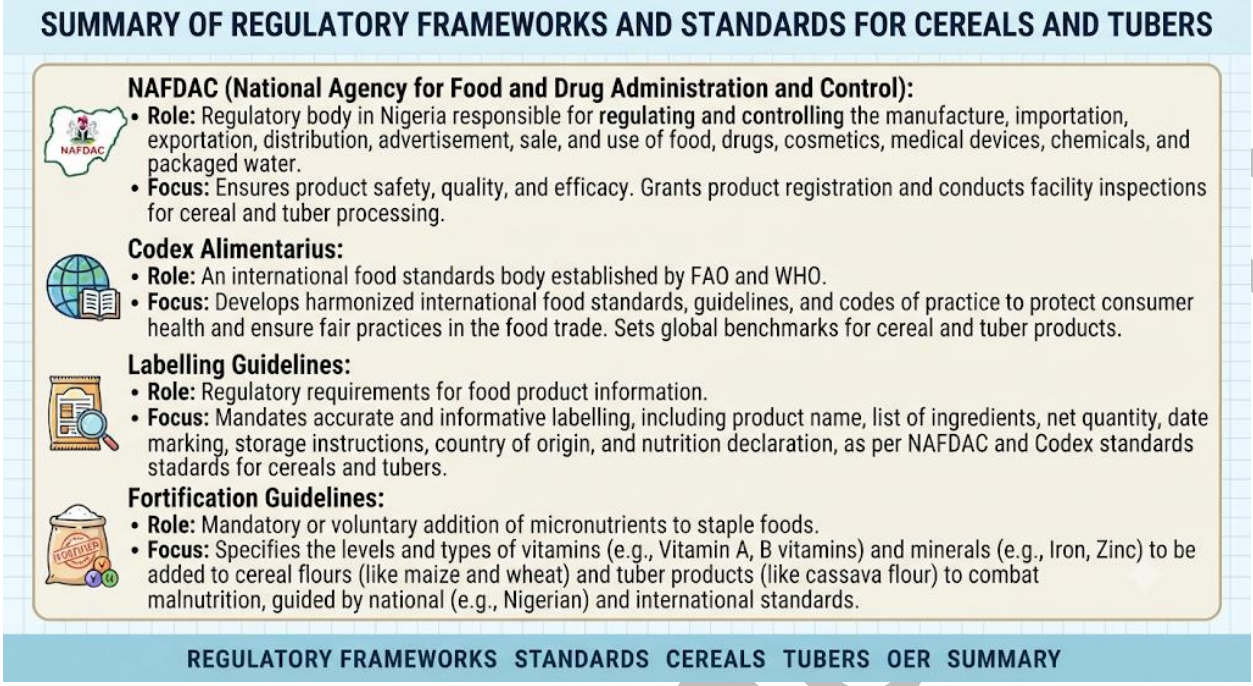


Box 5.5 Regulatory frameworks and standards in processing

Fill in the blank: Codex Alimentarius provides international _____ for food safety and fortification.

**Pilot questions 5.5**

1. What is the purpose of nutritional evaluation in processed products?
2. Name two parameters tested during nutritional evaluation.
3. Why is hygiene important in processing plants?
4. Which system is used alongside GMP to ensure food safety?
5. Name one international body that sets standards for food fortification.

**Series Summary**

This Series has explored **processing and enrichment technologies** for cereals and tubers. We began with the **principles of processing**, defining its importance, comparing traditional and modern methods, and examining nutritional impacts. We then studied **primary processing techniques**, including cleaning, grading, milling, grinding, fermentation, and germination. Next, we examined **secondary processing and product development**, focusing on extrusion, baking, fortified products, and novel innovations. We continued with **enrichment and fortification technologies**, highlighting nutrient enrichment strategies, fortification methods, and case studies. Finally, we concluded with **quality assurance and standards**, covering nutritional evaluation, safety and hygiene, and regulatory frameworks.

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By linking these discussions to the Series Learning Outcomes, you should now be able to explain processing principles, describe primary and secondary techniques, differentiate enrichment and fortification technologies, and evaluate quality assurance practices. This knowledge equips you to manage cereals and tubers from raw materials to enriched, safe, and innovative food products.

**Glossary of Terms**

- **Processing**: Transformation of raw crops into safe, nutritious, and usable forms.
- **Extrusion**: Forcing flour through heat and pressure to produce snacks and cereals.
- **Fortification**: Addition of nutrients to food products to improve dietary value.
- **Biofortification**: Breeding crops to naturally contain higher nutrient levels.
- **Germination**: Sprouting grains to increase vitamin content and mineral bioavailability.
- **Fermentation**: Microbial breakdown of carbohydrates to improve flavour and nutrition.
- **Nutritional evaluation**: Analysis of protein, fibre, vitamins, minerals, and energy in processed foods.
- **Good Manufacturing Practices**: Standards ensuring hygiene and safety in food production.
- **Codex Alimentarius**: International guidelines for food safety and fortification.
- **Novel innovations**: New product developments such as instant porridges and gluten-free bakery items.

**Concept Check Questions [Series 5]**

**Objective questions**

1. Processing helps to reduce post-harvest _____ and improve food safety. (Linked to SLO 5.1)
2. Germination of cereals increases _____ vitamins in the grain. (Linked to SLO 5.2)
3. Biofortification involves breeding crops to naturally contain higher _____ levels. (Linked to SLO 5.4)

**Short-answer questions**

4. List two traditional processing methods for cereals and tubers. (Linked to SLO 5.1)
5. State one example of a fortified cereal or tuber product. (Linked to SLO 5.3)

**Long-answer questions**

6. Compare traditional and modern processing methods, highlighting advantages and limitations. (Linked to SLO 5.1)

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- *Basic response*: Learners should mention pounding, sun-drying, fermentation vs. mechanised milling, extrusion.
- *Value-added response*: Outstanding learners may discuss efficiency, safety, cultural relevance, and scalability.

7. Evaluate quality assurance practices in processing and enrichment, considering nutrition, hygiene, and regulatory standards. (Linked to SLO 5.5)
    - *Basic response*: Learners should mention nutritional evaluation, GMP, HACCP, and compliance with standards.
    - *Value-added response*: Outstanding learners may connect these practices to consumer trust, public health, and international trade.

**Answers to Concept Check Questions [Series 5]**

1. Losses
2. B
3. Nutrient
4. Pounding, sun-drying
5. Iron-fortified maize meal
6. *Basic*: Traditional methods are simple and culturally relevant but less efficient; modern methods are efficient and safe but costly. *Value-added*: Modern methods support large-scale production and trade, while traditional methods remain vital in resource-limited areas.
7. *Basic*: Quality assurance ensures nutrition, hygiene, and compliance. *Value-added*: It builds consumer confidence, supports public health, and aligns with international standards.

**Answers to Pilot Questions [Series 5]**

**Part 5.1**

1. Transformation of raw crops into safe, usable forms
2. Reduces losses, adds value
3. Traditional: pounding; Modern: extrusion
4. Enhances protein digestibility
5. Removes fibre and micronutrients

**Part 5.2**

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1. To remove impurities and sort by quality
2. Flour
3. Improves digestibility
4. Ogi (fermented maize porridge)
5. Increases vitamin content

**Part 5.3**

1. Producing snacks and instant foods
2. Bread
3. Protein-enriched biscuits
4. Anaemia
5. Gluten-free bakery items

**Part 5.4**

1. To improve nutrient profile
2. Soybean enrichment
3. Premixes, coatings
4. Vitamin A cassava
5. They show practical applications of enrichment

**Part 5.5**

1. To confirm dietary adequacy
2. Protein, fibre
3. Prevents contamination
4. HACCP
5. Codex Alimentarius

**References and Attributions [Series 5]**

- Figures, plates, tables, and boxes were suggested as placeholders with AI prompts for generation. For example: “Create a labelled diagram showing fortification methods: premixes, coatings, biofortification” (Figure 5.4).
- Suggested open educational resource (OER) search strings included: “importance of processing cereals tubers diagram OER”, “fermentation germination cereals tubers OER

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summary", "fortified cereal tuber products OER summary", "regulatory frameworks standards cereals tubers OER summary".

- AI-generated placeholders were designed to illustrate concepts such as processing steps, enrichment strategies, fortification methods, and quality assurance practices.
- Attribution: Content developed from course outline provided in FST 501: Cereals and Tubers Technology.

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