FE 401 Food Technology
Dr. Fatih BALCI

Chapter 1: Food Technology and Entrepreneurship (Introductory Lecture)

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1. Purpose and Integration

Purpose:

This introductory lecture is designed to open the semester by equipping students with an entrepreneurial mindset before they begin their Food Technology projects. Rather than waiting until the end, we want every team to view their technical work through a startup lens from day one. By establishing this foundation in Week 1, students will:

- Recognize why food engineers can become successful entrepreneurs.
- Learn how to spot market needs and translate food-technology expertise into viable business ideas.
- Understand basic tools—Problem Statements, Minimum Viable Products (MVPs), and the Value Proposition Canvas—that will guide their project work all semester.
- Be encouraged, from the very start, to ask: "Could our project lead to a real food-tech venture? What improvements or pivots might increase its commercial potential?"

Integration:

This content replaces the standard first lecture in FE 401. It precedes any technical modules (cereal processing, dairy, legume technology, etc.). All subsequent project milestones (midterm check-ins, drafts, final presentations) will refer to the entrepreneurial concepts introduced here. Each project team will be asked throughout the semester to reflect on whether their technical solution can become a business idea and to document any "Entrepreneurial Insights" as they go.

2. Chapter Subheadings

1. **Why Food Engineers Make Great Entrepreneurs**
    - The natural link between process expertise and opportunity identification
    - Key trends in the food industry (health, sustainability, digital traceability)
    - Brief case examples of successful food-tech startups
2. **Finding and Refining a Business Idea**
    - Market-trend scanning and customer pain analysis
    - Brainstorming (SCAMPER, Kano Model) tailored to food-technology challenges
    - Writing a clear Problem Statement for a food-sector opportunity
3. **Minimum Viable Product (MVP) Strategies in Food Technology**
    - Definition and importance of an MVP
    - Low-cost MVP methods
    - How to plan a rapid "proof of concept" for a food idea
4. **Value Proposition Canvas Workshop**
    - Customer Profile: Jobs, Pains, Gains
    - Value Proposition: Products & Services, Pain Relievers, Gain Creators
    - Crafting and peer-reviewing a concise Value Proposition Statement
5. **Embedding Entrepreneurial Thinking into Semester Projects**

  - How to evaluate your project idea for startup potential from the very beginning
  - Identifying possible pivots or improvements that increase commercial viability
  - Requirement: each final presentation must include an "Entrepreneurial Insight" slide

3. How This Introductory Lecture Supports Semester-Long Projects

- **Early Mindset Shift:** By dedicating the very first class to entrepreneurship, students begin thinking not just like engineers, but like founders. They learn that every recipe reformulation, equipment selection, or process optimization can spark a business concept.
- **Iterative Reflection:** Throughout Weeks 2–12 (covering cereal, dairy, legume, and other modules), teams will revisit the tools introduced here (Problem Statement, MVP, Value Proposition Canvas). Each milestone—midterm design review, prototype test, draft report—will include a quick check: "Does this advance our business idea? Do we need to pivot?"
- **Final Presentation Requirement:** At semester's end, every team's slide deck must include one slide titled **"Entrepreneurial Insight."** That slide will answer:
  1. **"Did our project inspire a concrete business idea?"**
  2. **"What improvements or pivots would be needed to make it a viable startup?"**
  3. **"Which specific venture concepts emerged from our technology area?"**

By explicitly requesting this in Week 1, teams know from day one that their technical design must serve both academic and entrepreneurial goals.

4. Summary of Objectives

- **Objective 1:** Explain why a background in food engineering—understanding raw materials, process controls, and safety—naturally positions students to identify and launch food-technology ventures.
- **Objective 2:** Teach structured techniques so students can generate at least one preliminary food-sector business idea before they even choose a project topic.
- **Objective 3:** Introduce Minimum Viable Product (MVP) concepts, demonstrating how to test an early-stage food prototype with minimal resources (e.g., manual assembly, simple landing page, or "concierge" sample delivery).
- **Objective 4:** Guide students through completing a Value Proposition Canvas—mapping customer Jobs, Pains, Gains to their proposed Product, Pain Relievers, and Gain Creators—so they can clearly articulate why their idea matters.
- **Objective 5:** Ensure that, by Week 1, students understand they will be evaluated not only on process design but also on their ability to translate that design into a potential business.

Chapter 1: Food Technology and Entrepreneurship

Introduction: The Startup in the Lab

Welcome to FE 401. This chapter is designed to fundamentally shift your perspective on the work you will do this semester and throughout your careers. I want you to view every technical food technology project not just as a scientific exercise, but as the potential foundation for a new business venture. From day one, we will equip you with an entrepreneurial mindset. My goal is for you to learn to see beyond the process flow diagram and the lab bench, to identify the commercial opportunities embedded within your technical challenges, and to develop the skills to act on them.

1. Why Food Engineers Make Great Entrepreneurs

1.1. The Engineer's Advantage: From Process to Opportunity

It is my firm belief that food engineers possess a powerful and often underestimated advantage in the entrepreneurial world. Your deep knowledge of production systems, analytical thinking, and innate problem-solving abilities are the very same skills that build great companies. Where others see only a finished product on a shelf, you see the intricate web of steps, inputs, and transformations that brought it there. This unique perspective allows you to identify opportunities for innovation, efficiency, and value creation that are invisible to most. The ability to master complexity is your strategic edge.

Consider the intricate processes you are studying. Each represents a system where an opportunity might be hiding:

- **Oil Refining:** The multi-stage chemical refining process—encompassing Degumming, Neutralization, Bleaching, and Deodorization—is a prime example of mastering a complex system. An entrepreneur who understands these stages can pinpoint bottlenecks, develop more sustainable chemical alternatives, or find ways to extract valuable compounds from waste streams.
- **Cereal Processing:** The detailed steps in wheat cleaning and conditioning or the precise methods for oat processing demonstrate how a deep understanding of inputs and outputs can reveal business opportunities. Could a novel conditioning technique improve flour yield? Could a gentler oat rolling process create a new product category with superior texture and nutritional value?
- **Post-Harvest Technology:** The challenge of deterioration in fresh fruits and vegetables is a massive global problem. Solutions like controlled atmosphere (CA) storage are engineered responses to a biological process. An engineer who grasps the interplay of oxygen, carbon dioxide, and temperature can develop innovative coatings, monitoring sensors, or logistics systems that reduce food waste and create significant economic value.

1.2. Key Trends Shaping the Future of Food

Your technical skills are most powerful when applied to the major trends reshaping the food industry. By aligning your innovative efforts with these market forces, you can move from incremental improvements to transformative solutions.

Health and Nutrition Consumers are increasingly demanding food options that actively contribute to their well-being. This trend goes beyond simple calorie counting to a sophisticated interest in the functional properties of food. As engineers, you have the data to meet this demand. For example, understanding the fatty acid composition of different oils—knowing that olive oil is 77% monounsaturated fat while coconut oil is 92% saturated—allows you to formulate products that meet specific health targets. Similarly, knowledge of gluten-free cereals like rice and oats, and their unique processing requirements, positions you to create products for a growing market segment that seeks alternatives to wheat.

Sustainability The environmental impact of food production is under intense scrutiny. Consumers and regulators alike are demanding more sustainable practices. Your ability to analyze and optimize processes is critical here. For instance, data from pasta production reveals that durum wheat cultivation accounts for approximately 50% of the product's total carbon footprint. This insight tells an entrepreneur that the biggest opportunity for impact isn't in the factory but on the farm, perhaps through developing partnerships for regenerative agriculture or creating new, lower-impact grains. Likewise, a key opportunity lies in the systemic use of by-products, such as diverting bran, broken kernels, and bulgur flour from milling operations to be used as animal feed or higher-value 'upcycled' ingredients.

Process Automation and Control The food industry is rapidly moving toward greater technological control to enhance efficiency, consistency, and safety. The implementation of PLC-Based Systems to monitor and automate milling operations is a clear example. These systems provide real-time data that allow for precise adjustments, reducing waste and ensuring a consistent final product. For an entrepreneur, this trend opens doors for developing new sensors, software, or machinery that give food producers even greater control over their complex operations, leading to higher quality and lower costs.

1.3. Case Examples: From Lab to Market

To bring these ideas to life, let's consider a few hypothetical startups that could emerge directly from the principles studied in this course. Each is grounded in a specific technical insight that is leveraged to create a compelling business venture.

Startup Concept	Core Technology Insight
Vitelia Protein	Leverages advanced **membrane filtration techniques**, originally used for clarifying fruit juice, to efficiently isolate and purify high-value proteins from peas and lentils for the plant-based food market.
SavorShelf	Applies the principles of **Ultra-High Temperature (UHT) processing** to create a line of gourmet, preservative-free, ready-to-eat meals with a long shelf life, eliminating the need for refrigeration and targeting busy professionals.
Marigen	Develops a proprietary "waste-to-value" process to convert by-products from **fish processing**, such as skins and bones, into high-grade, odorless collagen peptides and calcium supplements for the nutraceutical industry.

Understanding your inherent advantages and the trends shaping our industry is the first step. The next is to develop a systematic process for finding and validating a business idea worth pursuing.

2. Finding and Refining a Business Idea

2.1. Identifying Market Needs and Customer Pains

A brilliant technical solution without a customer is just a science project. A successful business is built not on a great product, but on solving a real, meaningful problem for a specific group of people. The most effective way to uncover these problems is through a systematic process called **"customer pain analysis."** Instead of starting with an idea, you start by observing and understanding the struggles, frustrations, and unmet needs of a potential customer.

The **Customer Profile**, a core component of the Value Proposition Canvas, provides a clear framework for this analysis. It forces you to look at the world from your customer's perspective by mapping three key elements:

- **Customer Jobs:** These are the functional, social, or emotional tasks your customers are trying to accomplish in their work or life. A functional job might be "prepare a meal," while a social job could be "impress dinner guests," and an emotional job could be "feel secure about the food my family eats."
- **Pains:** These describe the negative outcomes, risks, and obstacles related to customer jobs. Pains are the problems you want to solve. They can be anything from frustrations and annoyances ("This takes too long") to significant risks ("I'm afraid of contamination").
- **Gains:** These are the outcomes and benefits your customers want to achieve. Gains are not just the opposite of pains; they represent aspirations. They can be required (the product must function), expected (it should be well-designed), desired (I'd love it if it integrated with my other tools), or even unexpected.

To illustrate, consider the "pain" of parents trying to find healthy snacks for their children. Their **job** is to provide a quick and nutritious option for school lunches or after-school activities. Their **pain** is the frustration of finding that most convenient snacks are loaded with sugar, artificial ingredients, or allergens. A corresponding **gain** they desire is the peace of mind that comes from giving their child something genuinely healthy that they will also enjoy eating. By deeply understanding this profile, you can start to formulate a solution that truly resonates.

2.2. A Framework for Brainstorming

Once you have a deep understanding of customer needs, you can begin generating solutions. Brainstorming should be a structured activity, not an unstructured free-for-all. Frameworks like the following can help guide your creative process:

- **SCAMPER:** This is a method that uses a set of directed questions to spark new ideas by looking at an existing problem or product from different angles: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse.

- **Kano Model:** This model helps classify customer preferences into different categories (e.g., Basic Needs, Performance Needs, Delighters). It's a powerful tool for prioritizing which features or attributes will have the greatest impact on customer satisfaction.

2.3. Crafting a Clear Problem Statement

Before you rush to build anything, it is critical to distill your insights into a concise and powerful Problem Statement. This statement frames the opportunity and serves as the North Star for your venture. It ensures that you and your team are aligned on exactly whose problem you are solving and why it matters.

A well-framed statement should clearly identify the customer, their goal, and the obstacle standing in their way. Here is a template you can use:

Our **[customer segment]** is trying to **[job to be done]** but is frustrated because **[pain/obstacle]**.

Based on our earlier example and the trends we've discussed, a food-tech problem statement could be:

*"Our **[young, health-conscious consumers]** are trying to **[find convenient, protein-rich snacks]** but are frustrated because **[current options are either high in sugar, contain animal products, or are processed with chemical additives]**."*

With a clear problem defined, the next crucial step is to test your proposed solution in the simplest, fastest, and cheapest way possible. This is the role of the Minimum Viable Product.

3. Minimum Viable Product (MVP) Strategies in Food Technology

3.1. What is an MVP and Why Does it Matter?

One of the biggest risks in entrepreneurship is investing time and resources to build a perfect product, only to discover that nobody wants it. The **Minimum Viable Product (MVP)** is a strategy designed to mitigate this risk. An MVP is not a smaller, cheaper version of your final product. As defined by Eric Ries, it is **"that version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort."** Its primary purpose is not to generate revenue but to learn. It is an experiment designed to test your core assumptions about the problem and your solution.

A successful MVP must accomplish three core things:

1. The customer must get real value out of using it.
2. The customer must provide valuable feedback that can guide future development.
3. It must test the most critical assumption: will a customer ultimately exchange something of value (money, time, data) for your solution?

3.2. Low-Cost MVP Methods for Food Ventures

Building a physical food product can be capital-intensive, but your initial MVP doesn't have to be a full-scale production run. There are several low-cost, service-based methods you can adapt to test your food venture idea.

The Concierge MVP In this model, you manually deliver the value of your product as a high-touch, personal service. You are simulating the final, automated product to learn directly from your first customers.

- **Food Venture Example:** To test a personalized nutrition plan and grocery delivery service, an entrepreneur wouldn't start by building an app and a logistics network. Instead, they would manually consult with a handful of early customers, create their meal plans by hand in a spreadsheet, and then personally shop for and deliver the groceries. This direct interaction would provide invaluable feedback on food preferences, pricing sensitivity, and the overall value of the service.

The Wizard of Oz MVP This method involves creating an impression of a fully functional, automated system, while behind the scenes, you are manually performing the tasks. The customer interacts with a polished front-end (like a website), but the back-end is powered by human effort.

- **Food Venture Example:** Imagine a website that claims to use a sophisticated algorithm to recommend custom spice blends for home cooks based on their taste profile. In a Wizard of Oz MVP, when an order comes in, an expert chef manually reviews the customer's preferences and creates the recommendation. This tests whether customers value the *outcome* (a custom spice blend) before you invest in building the complex technology to automate it.

3.3. Planning a "Proof of Concept"

While an MVP tests the business assumptions, a **Proof of Concept (PoC)** tests the core *technical* assumption of your idea. In food technology, this is often a small-scale, rapid experiment to see if your proposed process is feasible and delivers the desired result.

For example, if your idea is to create a new line of frozen vegetables with superior texture, you might hypothesize that a specific blanching technique will be effective. Drawing from our course materials, you could design a PoC: conduct a kitchen-scale trial to see if blanching a soft vegetable in a **2% Calcium chloride solution** effectively firms its texture before freezing. You could then gather immediate taste-test feedback from a small panel to validate the sensory outcome. This simple experiment proves the technical core of your idea before you scale up.

An MVP helps you test your business idea, but to design an idea that is worth testing in the first place, we turn to the Value Proposition Canvas.

4. Value Proposition Canvas Workshop

4.1. Deconstructing Value: The Two Sides of the Canvas

The **Value Proposition Canvas** is a powerful strategic tool that helps you visually map, design, and test how you create value for your customers. Its greatest strength is that it prevents you from falling in love with your own ideas and instead forces you to anchor everything you build in the tangible jobs, pains, and gains of your customers. The canvas is composed of two distinct sides: the Customer Profile and the Value Map.

The Customer Profile (The Circle) This side is dedicated to clarifying your understanding of the customer. It's about observing their world without judgment and without considering your solution yet.

- **Customer Jobs:** What your customers are trying to get done in their work and lives. These can be functional (e.g., *get from A to B*), social (e.g., *look good in front of peers*), or emotional (e.g., *feel secure*).
- **Pains:** The bad outcomes, risks, and obstacles that customers face. This includes anything that annoys or prevents them from getting a job done (e.g., *wasting time*, *high costs*, *feeling frustrated*).
- **Gains:** The positive outcomes and benefits customers require, expect, desire, or would be surprised by. This can include functional utility, social gains, positive emotions, and cost savings.

The Value Map (The Square) This side is where you design how you will create value for that customer. It outlines how your product or service will turn their pains into relief and their wants into reality.

- **Products & Services:** A list of what you offer. This is the bundle of items that helps your customers get their jobs done.
- **Pain Relievers:** A description of how, specifically, your products and services alleviate customer pains. How do you eliminate or reduce their frustrations, risks, and obstacles?
- **Gain Creators:** A description of how your products and services create customer gains. How do you produce the outcomes and benefits your customer expects, desires, or would be surprised by?

4.2. Workshop Activity: Crafting a Value Proposition

Let's put this tool into practice with a brief workshop activity.

1. **Hypothetical Idea:** We will work with a concept grounded in our course material: **"A shelf-stable, ready-to-drink yogurt smoothie using UHT processing and fortified with beneficial probiotic cultures."**
2. **Map the Customer Profile:** First, let's brainstorm the Jobs, Pains, and Gains for a target customer, for example, a **busy commuter**.
    - *Jobs:* Get a quick and healthy breakfast, have energy for the morning, avoid being late for work.
    - *Pains:* No time to prepare food, unhealthy fast-food options, midday energy crash, digestive issues.
    - *Gains:* Convenience, sustained energy, improved gut health, feeling good about their food choices.
3. **Map the Value Proposition:** Now, let's map how our UHT yogurt smoothie's features address the commuter's profile.

- *Pain Relievers:* The UHT processing means no refrigeration is needed, making it a "grab-and-go" solution. It eliminates the need for any preparation.
- *Gain Creators:* The formulation provides balanced nutrition for sustained energy, and the added probiotics directly address the desire for improved gut health.

4. **Achieve Fit:** The goal is to achieve what's called **"Fit."** This happens when the elements on your Value Map directly and powerfully address the most important jobs, extreme pains, and essential gains you identified in your Customer Profile.
5. **Draft a Statement:** Finally, synthesize the insights from your canvas into a concise Value Proposition Statement using this simple template:
6. For our example, this becomes:

These tools are not just for this lecture. They are meant to be applied directly to the projects you will be developing this semester.

5. Embedding Entrepreneurial Thinking into Your Semester Projects

5.1. Your Project as a Potential Startup

This brings us full circle. The concepts from this lecture—the engineer's advantage, customer pain analysis, Minimum Viable Products, and the Value Proposition Canvas—are the foundational toolkit you will use throughout the semester. I expect you to apply this entrepreneurial lens to every technical project you undertake.

From the very beginning, I want you to evaluate your project ideas for their startup potential using the following steps:

1. **Start with the Customer:** Before you begin perfecting a technical process, such as a new method for smoking fish, take a step back and create a Customer Profile. Who would be the ideal customer for this smoked fish? Is it a home cook, a gourmet chef, or a restaurant chain? What is their most significant pain point with existing products? Perhaps current options are too salty, not sustainably sourced, or lack consistent quality.
2. **Define Your Value Proposition:** Use the Value Proposition Canvas to explicitly connect your technical solution to customer value. How does your new smoking method relieve a major pain or create an essential gain? Is it a colder, gentler smoke that preserves delicate textures? Does it use a more sustainable wood source? Be specific about the value you are creating.
3. **Consider Pivots:** A "pivot" is a change in strategy without a change in vision. Constantly ask how a small change to your project could dramatically increase its commercial viability. For example, if your project focuses on optimizing oil extraction from soybeans, could you pivot the business model? Instead of planning to sell the commodity oil yourself, could you license your more efficient and proprietary extraction technology to large-scale producers for a royalty fee? This pivot changes your customer, your value proposition, and your entire business model, potentially creating a much more scalable venture.

5.2. Course Requirement: The "Entrepreneurial Insight" Slide

To ensure you are integrating these concepts into your work, each team's final project presentation for FE 401 **must** include a dedicated slide titled **"Entrepreneurial Insight."**

This slide must contain the following components:

- A concise **Problem Statement** that your technical project is solving for a specific customer.
- A summary of your **Value Proposition Canvas**, highlighting the key customer job, pain, and gain you are addressing with your solution.
- A brief description of a potential **Minimum Viable Product (MVP)** you could use to test your idea with real customers quickly and cheaply.

Remember, the most successful and impactful food technologies are not just technically elegant; they are those that solve real-world problems and create tangible value for people. I look forward to seeing the ventures you begin to build.

FE 401 Food Technology
Dr. Fatih BALCI
Cereal Processing Technology

Reference Textbooks:

- International Association for Cereal Science and Technology (ICC). (2023). *ICC Handbook of 21st Century Cereal Science and Technology.* Elsevier.
- Sharma, R., Dar, B. N., & Sharma, S. (2023). Cereal Processing Technologies. CRC Press.
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Content

1. **General Overview of Cereal Grains**

1.1. Definition and Importance

Cereals are raw agricultural commodities transformed through mechanical, thermal, and chemical processes into consumable or functional products. These grains are **structurally designed systems**, consisting of layers such as the bran, endosperm, and germ, each serving specific roles in food production and processing. Cereals like **wheat, rice, barley, maize**, and **oats** are widely utilized in **food engineering** to produce staples such as bread, pasta, breakfast cereals, and syrups.

1.2. Global Significance of Cereals in the Human Diet

Cereals are foundational to human nutrition and play an essential role in global food systems. Their versatility, availability, and nutritional value make them indispensable staples for billions of people worldwide.

1.2.1. Core Energy Source

Cereals provide the majority of caloric intake for a significant portion of the global population, forming the backbone of many diets:

Contribution to Diet: Cereals contribute 50–70% of daily caloric intake globally due to their high carbohydrate content.

Regional Staples:

- Rice is a primary food source for over half the global population, particularly in Asia.
- Wheat dominates diets in Europe, North America, and the Middle East in forms like bread and pasta.
- Maize is critical in Africa and Latin America, where it is consumed as tortillas, porridge, or snacks.

1.2.2. Nutritional Significance

Cereals are not only energy-rich but also provide essential nutrients:

Carbohydrates: A readily digestible energy source from starch.

Proteins: While lower in essential amino acids, cereals like wheat contain proteins (e.g., gluten) that are vital for many food structures.

Fiber: Whole grains (e.g., oats, barley) are high in dietary fiber, supporting gut health and reducing chronic disease risks.

Micronutrients: Bran layers are rich in B vitamins (e.g., thiamine, niacin) and minerals such as iron, zinc, and magnesium.

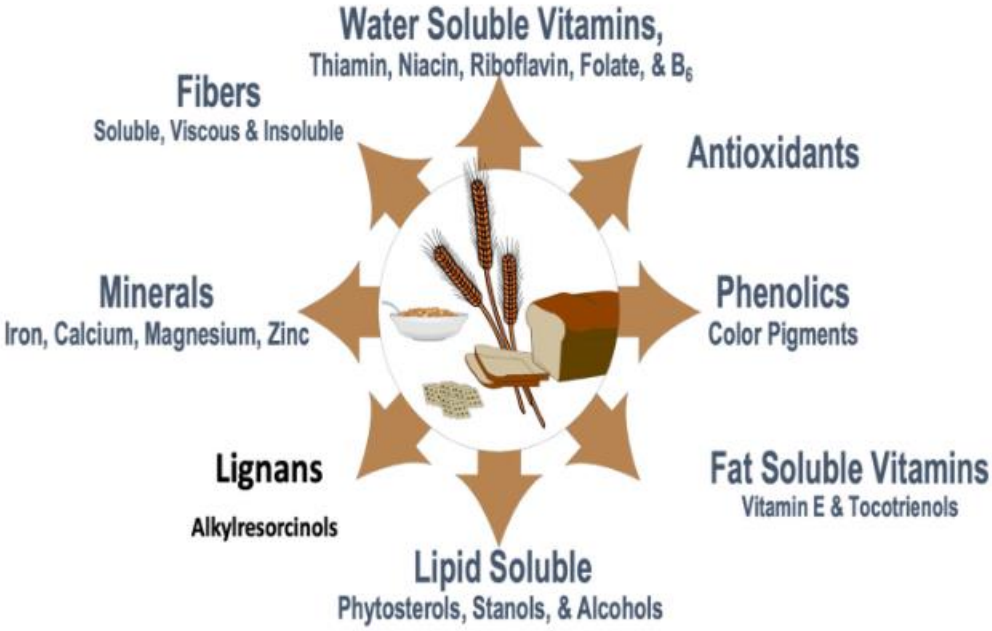

Figure 1 Whole grain components

1.2.3. Global Dependence on Cereals as Staple Food

Cereal consumption varies by region but consistently forms a significant portion of the global diet:

Wheat: Bread, pasta, and bakery products are key foods in Europe, North America, and parts of Asia.
Rice: Integral to diets in Asia, consumed as steamed rice or processed into noodles.
Maize: A staple in Africa and Latin America, used for tortillas, porridges, and snacks.
Barley: Common in brewing, soups, and health foods.
Oats: Popular in health-focused diets, used in breakfast cereals and snacks.

1.2.4. Industrial and Processed Food Applications

Cereals are the foundation for many processed and packaged foods:

Milled Products: Flours and semolina are used in bread, pasta, and baked goods.
Breakfast Cereals: Oats and corn are processed into flakes and puffs for ready-to-eat products.
Snacks and Syrups: Maize is used in corn syrups and puffed snacks, while rice and wheat are used in gluten-free products.

1.2.5. Contribution to Food Security

Cereals are essential for feeding a growing global population due to their:

High Yields: Cereals like wheat, rice, and maize produce large quantities per hectare, supporting large populations.
Ease of Storage: With low moisture content, cereals are easy to store and transport, making them ideal for long-term use and trade.
Affordability: Cereals are relatively cost-effective and accessible, making them a dietary cornerstone for low-income populations.

1.2.6. Economic Importance

Cereal production drives economies worldwide:

- **Global Trade**: Wheat, rice, and maize are some of the most traded commodities.
- **Livelihoods**: The cereal industry supports millions of farmers, millers, and food processors globally.

1.2.7. Sustainability and Future Perspectives

Cereals also contribute to environmental and nutritional sustainability:

- **Whole Grains**: Increased use of whole grains helps retain nutrients and reduce processing waste.
- **By-Products**: Bran and husks are repurposed for animal feed, biofuels, or biodegradable materials.
- **Breeding for Climate Resilience**: Development of drought- and pest-resistant cereal varieties supports sustainable agriculture.

Cereals remain the cornerstone of global food systems, meeting nutritional needs while providing economic stability and sustainability opportunities. Their adaptability to various diets and regions ensures their ongoing importance in addressing global food challenges.

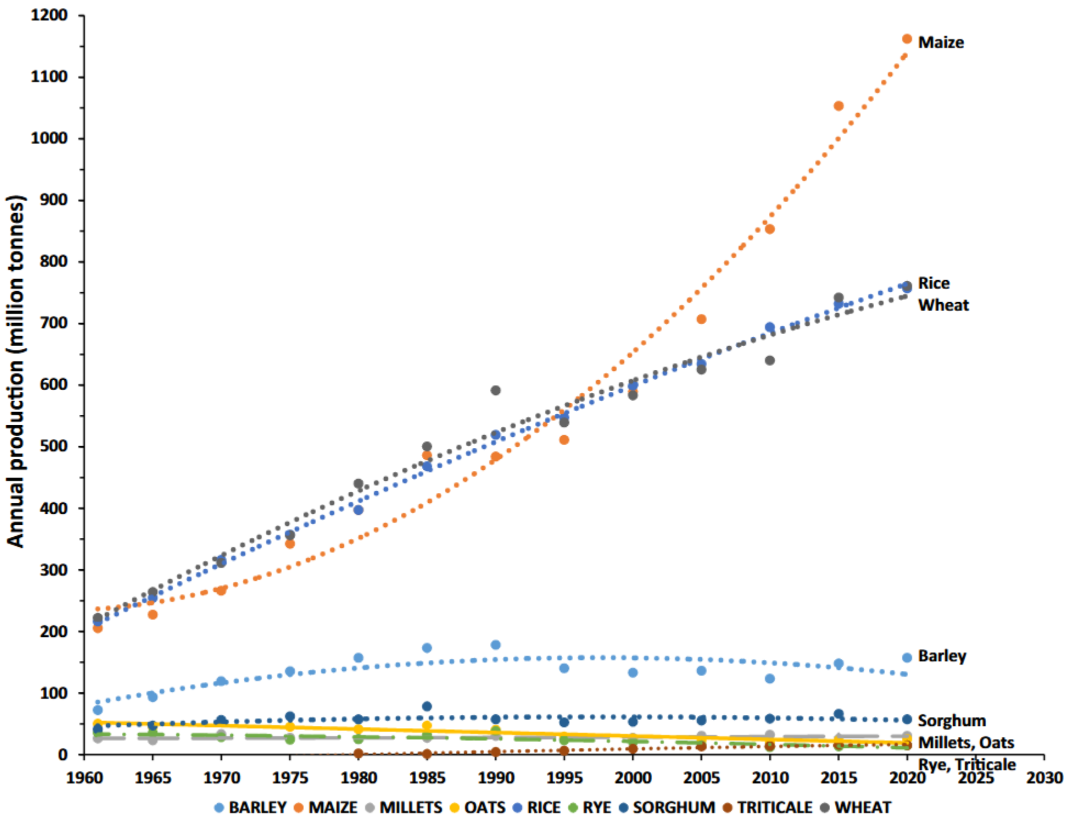

FIGURE 1.1 Trends in the production (worldwide) of the more significant cereal species over the period 1961 to 2020. Maize, Wheat, Rice, Barley, Sorghum (dotted lines), Millets (long dashes), Oats (solid), Rye (alternate dashes and dots), Triticale (dots). *Based on FAOSTAT data.*

Figure 2 Trends in the productions of the cereals

1.3. Types of Cereal Grains

a. Wheat (Triticum spp.)

Wheat, one of the most widely cultivated cereal crops, is classified into hard and soft varieties, each suited for distinct applications.

Hard vs. Soft Wheat: Hard wheat has a high protein content, particularly gluten, making it ideal for bread and pasta production. Gluten provides the elasticity and strength required for leavened products and pasta dough, enabling them to maintain structure and texture. Soft wheat, on the other hand, is low in protein and produces finer, softer flour. It is primarily used for making biscuits, pastries, and other baked goods that require a tender crumb.

Applications: Bread production relies on hard wheat due to its strong gluten network, which traps gases during fermentation for volume and texture. Pasta-making benefits from durum wheat, a hard wheat species known for its high protein content and yellow semolina. Soft wheat flour is a staple in biscuit production, contributing to the light, crumbly texture desired in these products.

b. Rice (Oryza sativa)

Rice is a globally significant cereal grain, with its varieties and nutritional benefits making it indispensable in various cuisines and food industries.

Japonica vs. Indica Varieties: Japonica rice is short-grained, sticky, and commonly used in sushi, risottos, and desserts due to its high amylopectin content. Indica rice, a long-grained variety, remains separate and fluffy after cooking, making it suitable for pilafs and fried rice. The structural differences in starch composition influence the culinary applications and sensory properties of these rice types.

Nutritional Importance: Rice is naturally gluten-free, making it an essential ingredient in gluten-free diets. It is also a key source of energy, primarily from carbohydrates, and is often fortified with vitamins and minerals to address nutritional deficiencies. Gluten-free rice flour is widely used in baking and as a thickener in processed foods, catering to individuals with celiac disease or gluten sensitivities.

c. Barley (Hordeum vulgare)

Barley is a versatile cereal grain with applications ranging from beverage production to health-focused food products.

Use in Malting and Brewing: Barley is a primary raw material in the malting and brewing industries. The malting process converts barley starches into fermentable sugars, essential for beer and whiskey production. Its husk structure and enzyme content make it ideal for brewing, providing clarity and body to the beverages.

Nutritional Value and Applications: Barley is rich in dietary fiber, particularly beta-glucans, which are known to lower cholesterol levels and support heart health. This nutritional profile makes barley a key ingredient in health foods such as whole-grain bread, breakfast cereals, and soups. Its nutty flavor and chewy texture further enhance its appeal in healthy meal preparations.

d. Oats (Avena sativa)

Oats are highly regarded for their exceptional nutritional content and versatility in various food products.

High Fiber Content and Health Benefits: Oats are an excellent source of beta-glucans, a type of soluble fiber that has been shown to reduce blood cholesterol levels and improve cardiovascular health. Additionally, oats are rich in essential nutrients, including manganese, phosphorus, and magnesium, making them a superfood in dietary contexts.

Applications: Oats are a staple ingredient in breakfast cereals, including porridge, granola, and muesli. Their versatility extends to snack products such as oat bars and cookies, where their nutritional profile and chewy texture are highly valued. The growing demand for plant-based and health-conscious snacks has further popularized oats in functional food markets.

1.3.1. Structure of Cereal Grains

a. Key Components of a Grain

Bran

The bran is the outer protective layer of the grain, comprising several layers such as the pericarp and seed coat. It is rich in dietary fiber, minerals (like iron and magnesium), and antioxidants (such as phenolic compounds). Bran accounts for approximately 13-16% of the grain's weight. It provides bulk to the diet and is a vital component in whole-grain products, contributing to their health benefits such as improved digestion and reduced risk of chronic diseases.

Endosperm

The endosperm is the largest portion of the grain, making up 83-85% of its mass. It is composed predominantly of starch and proteins and serves as the primary source of energy for the grain's development. The endosperm is the main component used in flour production, with its starch contributing to the texture and structure of baked goods.

Germ

The germ is the nutrient-rich embryo of the grain, constituting about 2-3% of its weight. It contains oils, vitamins (notably vitamin E and B-complex vitamins), and enzymes essential for sprouting and growth. Despite its small size, the germ is a powerhouse of nutrients and is often used in health-focused products. However, its high oil content makes it prone to rancidity, reducing its shelf life when included in flour.

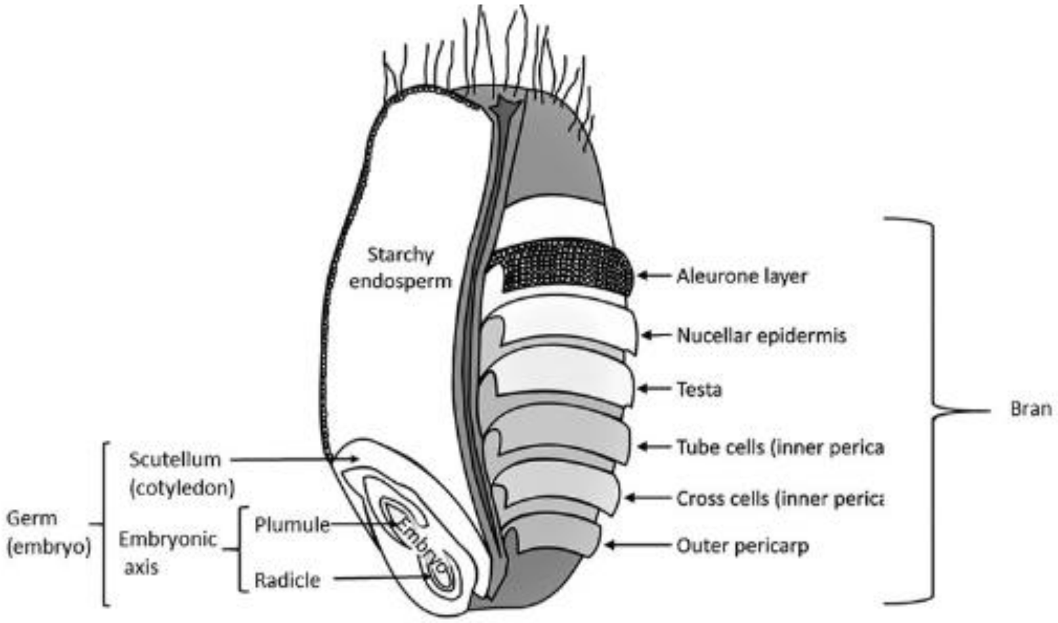

Figure 3 Wheat Structure

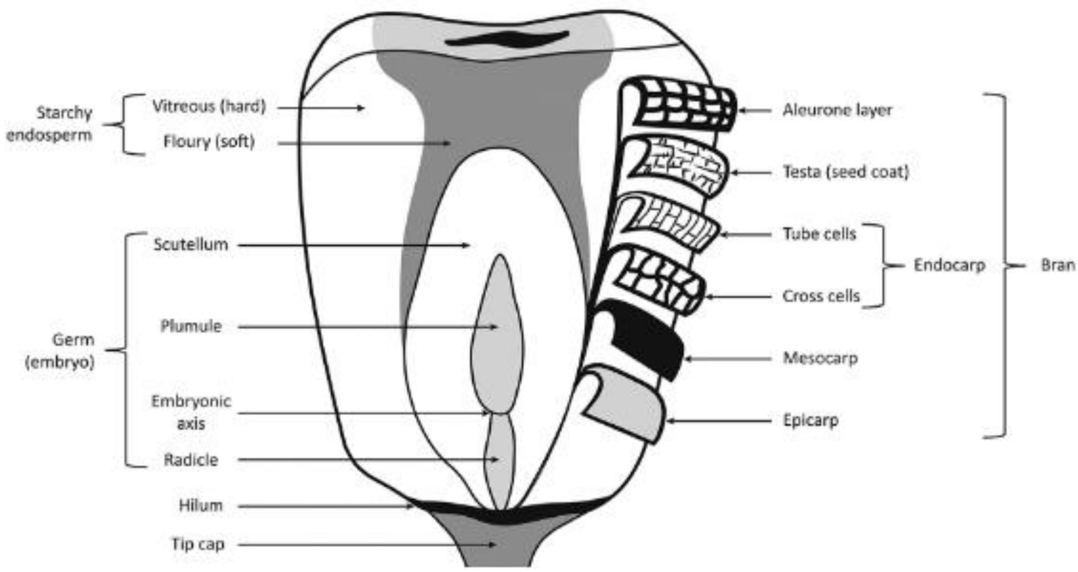

Figure 4 Corn Structure

b. Microscopic Structure of a Grain

The microscopic structure of cereal grains includes several distinct layers and tissues, each playing a critical role in grain functionality:

Pericarp

The pericarp is the outermost layer of the grain, part of the bran. It acts as a physical barrier, protecting the inner contents from physical damage and microbial invasion.

Seed Coat

The seed coat lies beneath the pericarp and provides additional protection to the endosperm and germ. It also helps prevent water loss and regulates gas exchange during storage.

Aleurone Layer

The aleurone layer is a single layer of living cells found at the boundary between the bran and the endosperm. It is rich in proteins, lipids, and enzymes, playing a crucial role in the germination process by releasing nutrients from the endosperm to support sprouting.

1.3.2. Chemical Composition of Cereal Grains

Cereal grains are staple foods globally and are valued for their diverse nutritional profile, which includes carbohydrates, proteins, lipids, vitamins, minerals, and phytochemicals. Each component plays a critical role in the functional and health properties of cereals.

a. Carbohydrates

Carbohydrates are the primary constituents of cereal grains, accounting for 60-80% of their dry weight.

Starch: Starch is the main carbohydrate, stored in the endosperm, and consists of two polysaccharides: amylose and amylopectin. The amylose-to-amylopectin ratio affects the cooking and textural properties of grains. For instance, rice varieties high in amylopectin (e.g., Japonica rice) are sticky, while those high in amylose (e.g., Indica rice) are firm and separate when cooked.

Dietary Fiber: Found primarily in the bran, dietary fiber includes cellulose, hemicellulose, and beta-glucans (in oats and barley). Fiber promotes digestive health, helps regulate blood sugar levels, and reduces cholesterol. Whole grains, which retain the bran, are particularly rich in fiber, offering significant health benefits compared to refined grains.

b. Proteins

Proteins contribute to 7-15% of the dry weight of cereal grains, with variations based on the grain type.

Gluten Proteins: In wheat, gluten proteins—gliadin and glutenin—form the gluten matrix, which is critical for breadmaking. Gluten provides elasticity and strength to dough, enabling it to trap gases during fermentation and create a well-structured loaf.

Non-Gluten Proteins: Cereals like rice and oats lack gluten-forming proteins. Rice contains albumins and globulins, making it suitable for gluten-free diets. Oats also contain avenins, which are non-toxic to most individuals with gluten sensitivity, furthering their use in gluten-free products.

c. Lipids

Lipids are concentrated in the germ, making up 2-5% of the grain's weight.

Functionality: Lipids contribute to the flavor and texture of cereal-based products. They also affect the shelf life of grains and flours due to their susceptibility to oxidation, particularly in whole grain and germ-enriched products.

Nutritional Value: These lipids include essential fatty acids, such as linoleic acid, which are important for heart health.

d. Vitamins and Minerals

Cereal grains are valuable sources of essential micronutrients, though their content varies across the grain's anatomical parts.

Bran: The bran is rich in B vitamins (e.g., thiamine, niacin, riboflavin) and trace minerals like iron, zinc, and magnesium. These nutrients are vital for energy metabolism and overall health.

Nutrient Loss in Milling: During milling, the removal of the bran and germ significantly reduces the grain's nutrient content. Enrichment strategies, such as adding back iron and B vitamins to refined flours, aim to counteract these losses and improve nutritional quality.

e. Phytochemicals

Phytochemicals are bioactive compounds found in cereals, with notable health implications.

Antioxidants and Polyphenols: These compounds, concentrated in the bran, help neutralize free radicals, reducing the risk of chronic diseases like cardiovascular disease and cancer.

Phytates: Present in the bran, phytates act as antioxidants but can also bind to minerals like calcium and zinc, reducing their bioavailability. This dual effect highlights the importance of balancing the intake of whole grains and processed grains to optimize nutrient absorption.

By understanding the chemical composition of cereal grains, we can better appreciate their role in nutrition and food applications. This knowledge informs strategies for product development, such as enhancing dietary fiber in whole-grain products or fortifying refined cereals with vitamins and minerals to address nutrient deficiencies.

1.3.3. Sustainable Perspectives in Cereal Production

Sustainability in cereal production involves minimizing the environmental impact of agriculture and processing while maximizing efficiency and resource use. Efforts focus on improving processing techniques and adopting sustainable farming practices to meet global demand without depleting resources.

a. Impact of Processing

Cereal processing, particularly milling, plays a significant role in both resource consumption and the nutritional quality of final products.

Milling and Nutrient Loss: Milling transforms whole grains into refined flours by removing the bran and germ. While this improves the shelf life and texture of flour, it also leads to a significant loss of dietary fiber, vitamins, and minerals. To address this, by-products such as bran and germ are increasingly utilized in health-focused products, animal feed, or industrial applications, reducing waste and enhancing sustainability.

Energy-Efficient Milling Techniques: Modern milling processes focus on reducing energy consumption through advanced equipment, such as roller mills and purifiers, and automated systems that optimize workflow. Technologies like heat recovery systems and precision milling minimize energy use and improve yield, supporting both economic and environmental sustainability.

b. Sustainability in Agriculture

Sustainable agricultural practices ensure that cereal production can meet present and future food demands while preserving environmental health.

Crop Rotation and Reduced Water Use: Crop rotation improves soil fertility and reduces dependency on synthetic fertilizers. For example, alternating cereal crops with legumes helps naturally replenish nitrogen levels in the soil. Additionally, advanced irrigation techniques, such as drip irrigation and water-sensing technology, reduce water usage in cereal farming, addressing concerns about resource scarcity.

Organic Cereal Production: Organic farming eliminates the use of synthetic pesticides and fertilizers, emphasizing natural methods like composting and biological pest control. Organic cereals have gained significant market potential, driven by consumer demand for environmentally friendly and chemical-free food products. Though organic production can have lower yields, its benefits to soil health and biodiversity contribute to long-term agricultural sustainability.

Sustainable practices in cereal production are essential for balancing the nutritional needs of a growing global population with the finite resources of our planet. Integrating efficient processing technologies and environmentally conscious farming methods represents a vital step toward a more sustainable food system.

1.4. Cereal Technology

Grains, commonly referred to as 'cereals' or 'cereal grains', are the edible seeds of specific grasses belonging to the Poaceae (also known as Gramineae) family.

True Cereal Grains

There are several different types of grains found within the true cereal grains which are from the botanical family 'Poaceae' including wheat, oats, rice, corn (maize), barley, sorghum, rye, and millet.

Pseudo-Cereal Grains

The 'pseudo-cereal' group are not part of the Poaceae botanical family, in which 'true' grains belong, however they are nutritionally similar and used in similar ways to 'true' grains. Many of these, such as amaranth, buckwheat and quinoa, are not actually grains but are in fact seeds from several different plant species external to the Poaceae family. As such, they are not by definition 'true' grains, yet they are considered 'pseudo-cereals' since their overall nutrient composition is similar, and they are prepared and used in similar ways to 'true' grains. Pseudo-cereals are increasingly being used in the manufacture of niche breads, flatbreads, crispbreads, pasta, breakfast cereals and snack bars as well as on their own as alternatives to rice, pasta and couscous.

Cereals are integral to food engineering due to their versatility and functionality. Here's how key cereals like wheat, rice, barley, maize, oats, and bulgur are transformed into widely consumed staples using specific engineering processes:

1.4.1. Wheat Processing Technology

Staple products such as flour, pasta, bulgur, biscuits, and other bakery items play a crucial role in diets worldwide. Bread production, a fundamental process in this category, begins with the milling of wheat grains into fine flour. This flour is then combined with water, yeast, and salt to form dough, which is a viscoelastic mixture crucial for gas retention and structure. Engineering principles, especially rheology, are employed to enhance the dough's elasticity and ability to trap gases produced during fermentation, ensuring a soft and airy bread texture.

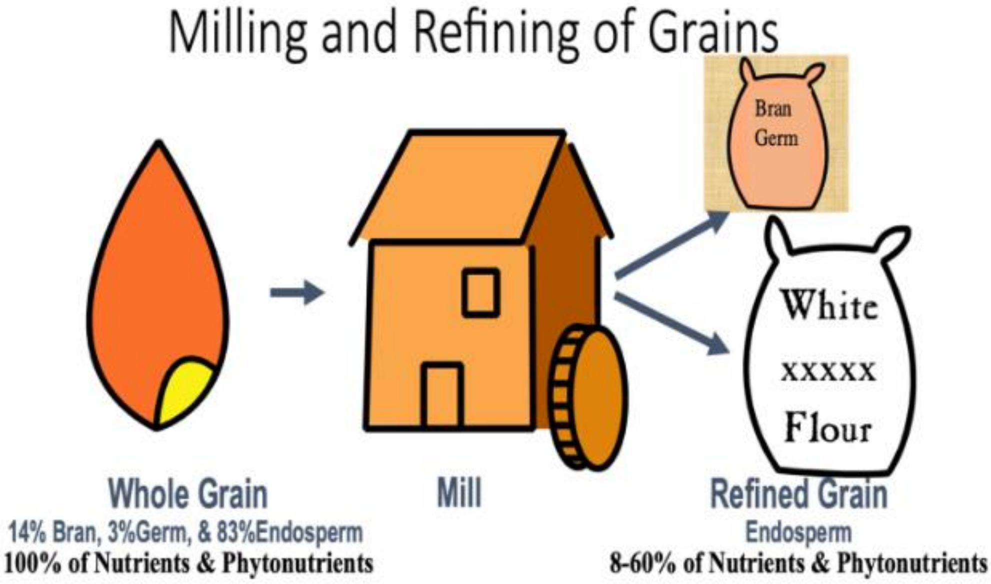

Figure 5 Cereal Processing

The technological advancements in bread production include continuous mixing systems, which enable the uniform blending of ingredients on a large scale. Modern proofing chambers are another key innovation, providing controlled environments for dough fermentation to ensure consistent rise and flavor development. These technologies together ensure high efficiency, consistent quality, and speed in bread manufacturing, meeting the demands of both mass production and artisanal standards.

1.4.1.1. Flour Production Technology

Flour milling is a process with ancient roots, tracing back to the manual grinding of wheat grains between stones to produce coarse flour. Early methods relied on simple stone grinding, resulting in wholemeal flour where the bran and germ were ground alongside the endosperm, making separation difficult. Over time, flour milling evolved from a domestic process to industrial-scale operations powered by wind or water. The development of roller milling in the 19th century revolutionized the industry, allowing for the efficient separation of the starch-rich endosperm from the bran and germ. This innovation enabled the production of finer, whiter flours with improved baking qualities.

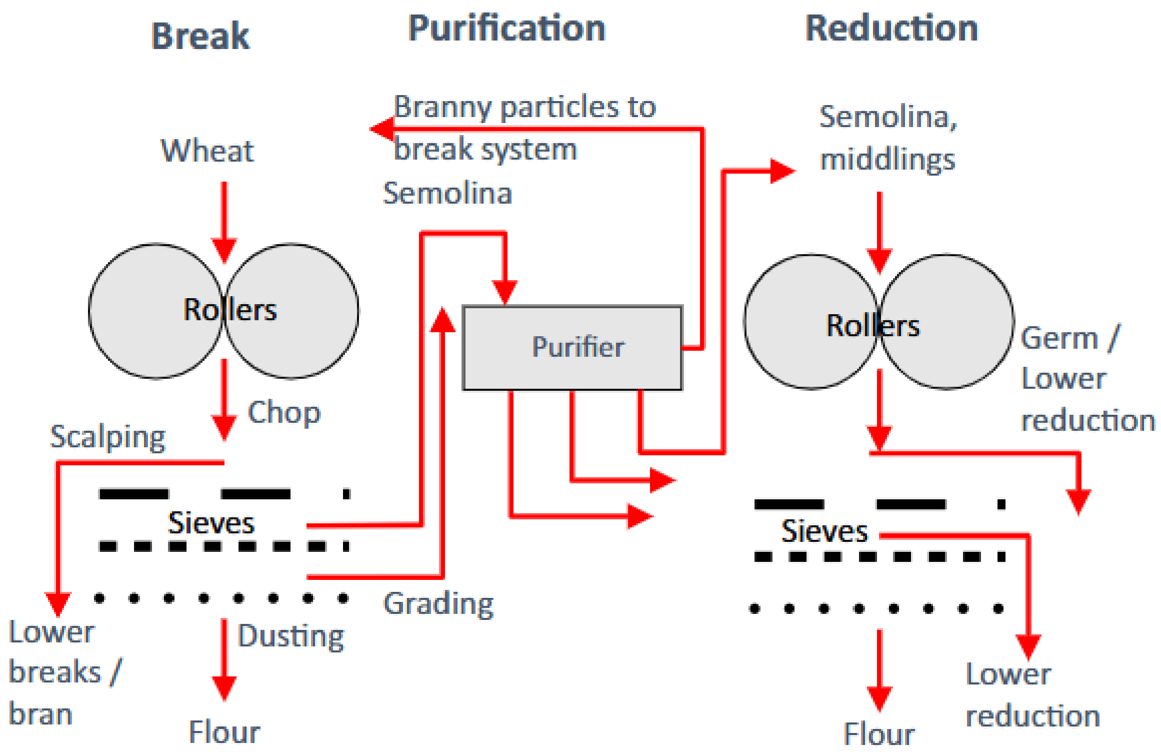

Figure 6 Principal steps in wheat milling

Modern flour milling focuses on maximizing yield, optimizing separation processes, and meeting the demand for "white" flour, which is free of bran and germ particles. The industry's advancements have also paralleled developments in cereal science, enabling the selection of wheat varieties tailored to specific baking requirements. Standard testing methods are now employed to assess the quality of grains and flour, ensuring they meet bakers' needs.

A. Arrival of Wheat at the Mill

Wheat enters the mill from various local and international sources. Upon delivery, it undergoes evaluations to ensure purity and compliance with agreed specifications. Key processes include:

Sampling: Manual or pneumatic samplers collect representative samples from the load. These samples are tested for impurities, moisture, protein content, and the presence of toxins like ergot.

Screening: Tests using sieves or visual inspections help identify non-wheat contaminants such as straw, stones, or other grains. Impurities are categorized as:

- **Extrinsic impurities**: Materials introduced during harvesting or storage, such as stones and dirt.
- **Intrinsic impurities**: Natural contaminants, including shriveled grains, weed seeds, or ergot (a toxic fungal infection).

Quality Testing: Methods like Near-Infrared Spectroscopy (NIRS) provide rapid assessments of wheat moisture, protein, and alpha-amylase activity, critical for determining suitability for breadmaking.

B. Wheat Cleaning Before Milling

Wheat undergoes multiple cleaning stages to remove impurities and prepare it for milling:

1. **Preliminary Cleaning**: Large debris and ferrous contaminants are removed using coarse sieves and magnets.
2. **Dry Cleaning**: In the screenroom, impurities are separated by size, density, and shape using:
   - **Aspiration**: Air currents remove light impurities such as dust and chaff.
   - **Sifters**: Multi-deck sieves separate large debris, sand, and dust from wheat grains.
   - **Density-based Machines**: Inclined sieves and controlled airflows separate dense materials like stones.
   - **Shape-based Machines**: Cylinder or disc separators remove non-wheat grains and seeds.
3. **Scouring**: Paddles gently abrade the grains to remove surface dirt and dust.
4. **Optical Sorting**: Machine vision systems remove blemished or undersized grains.

These steps ensure high purity and reduce microbial loads, preparing the wheat for milling.

C. Wheat Conditioning

Conditioning, or tempering, involves adding water to the wheat to achieve optimal moisture levels. This process:

- Softens the bran for easier removal.
- Improves endosperm separation.
- Enhances flour color and reduces ash content.

Conditioned grains are left to rest for up to 24 hours, allowing moisture to distribute evenly. Modern mills may use debranning as an alternative to traditional conditioning, employing abrasive machines to remove outer bran layers without disrupting the endosperm.

D. Milling Process

Modern flour milling is designed to maximize the yield of high-quality white flour while efficiently separating the different components of wheat grains. This is achieved through a series of mechanical operations, each optimized for precision and minimal waste.

Break System

The break system is the initial stage of the milling process. Wheat grains are passed through fluted rollers that crush the kernels to release the endosperm (starch-rich interior) from the bran (fiber-rich outer layers). The fluted rolls rotate at different speeds, creating a scissor-like cutting action. This controlled crushing minimizes the fragmentation of bran, preserving its integrity while effectively separating it from the endosperm.

The result of the break system is a coarse, granular material called semolina, along with some flour and bran-rich fragments. This mixture is then sieved to separate the components:

- **Flour**: Finely ground particles are collected for immediate use or blending.
- **Semolina**: Coarse particles of endosperm are directed to the next stages for further refinement.
- **Bran**: Larger bran fragments are returned to subsequent break rolls for additional processing.

Scalping, Grading, and Dusting

Following the break system, the mixed materials are processed through oscillating sieves, which sort them based on size and density. This stage includes:

Scalping: Removes larger bran fragments ("overtails") from the mixture, preparing them for additional milling.

Grading: Separates coarse and fine semolina particles, which are then sent to purification systems for further cleaning.

Dusting: Extracts fine flour particles during sieving, ensuring their purity and directing them to the blending process.

Each separation step is crucial for isolating clean, high-quality flour while minimizing contamination from bran and other non-endosperm materials. This staged approach ensures efficient utilization of the wheat kernel and maximizes the production of premium flour.

Purification

The purification stage is critical for ensuring the semolina's cleanliness and quality before further processing. Purifiers are specialized machines that use a combination of sieving and airflow (aspiration) to separate semolina from bran particles and other impurities.

- **How It Works**:
  Sieving: Stratifies materials by size; larger and denser particles (bran fragments) are separated from lighter semolina granules.
  Aspiration: Airflow lifts lighter bran particles away from the heavier semolina, improving its purity.
- **Outcome**: The purified semolina, free of bran and specks, is directed to the reduction system for further grinding.

Reduction System

The reduction system involves progressively grinding the purified semolina into finer flour. Smooth-surfaced rolls are used in this stage to minimize damage to the flour's structure.

- **Key Features**:
  Gradual Grinding: The use of multiple reduction stages prevents excessive heat generation, which could negatively impact flour quality and nutritional value.
  Uniform Particle Size: Advanced sizing systems may be employed to achieve consistent flour granulation, ensuring optimal performance in baking and other applications.
- **Outcome**: This stage produces fine white flour suitable for breadmaking and other high-quality applications.

Scratch System

The scratch system focuses on extracting residual endosperm from bran-rich materials, increasing overall yield.

- **Process**:
  - Bran fragments containing small amounts of endosperm are passed through finely fluted rolls.

- The rolls gently scrape the remaining endosperm off the bran without excessive grinding.
- **Quality Implications**:
    - While this step improves the total flour yield, the extracted flour is lower in quality due to higher bran content.
    - This flour is often used for non-bread applications, such as industrial or animal feed products.

Flour Dressing

The final step in the milling process, flour dressing, ensures that only the highest-quality flour is collected.

- **How It Works**:

  Sieving: Uses fine mesh screens to separate flour from any remaining bran or germ particles.

  Purity: Ensures the flour meets required standards for texture, color, and performance.
- **Outcome**: The result is clean, high-grade flour that is ready for packaging and use in baking or other culinary applications.

E. Blending and Final Output

Flour from different stages is blended to create the desired product. For example:

Straight-run flour: A combination of all machine flours.

Patent flour: A low-extraction, high-quality flour with low ash content.

Flour milling is a continuously evolving process, incorporating advanced technologies to optimize yield, reduce energy consumption, and meet specific quality standards. The integration of cleaning, conditioning, and mechanical separation ensures the production of high-quality flour tailored to the needs of bakers and food manufacturers.

1.4.1.2. Bulgur Processing Technology

Bulgur, a semi-ready or ready-to-eat product made from wheat, is a staple food widely consumed in many parts of the world. With a production of approximately 1.5 million tons annually in Turkey and 250,000–300,000 tons in the USA, its popularity stems from its nutritional value, long shelf life, dietary fiber content, and relatively low cost. Bulgur production involves three main stages: cleaning, bulguration (cooking and drying), and milling. Each stage requires precise process control and expertise to ensure high-quality output.

A. Raw Material Receiving and Cleaning

The main raw material for bulgur production is durum wheat due to its:

- Yellow color, hard texture, and vitreous appearance.
- High protein content, which enhances the quality and reduces stickiness during cooking.

Cleaning Process:

Pre-Cleaning: Initial removal of coarse impurities like stones, metals, and foreign materials using sieves and magnetic separators.

Main Cleaning: Combines sieves, aspirators, destoners, and gravity tables to remove fine impurities, light kernels, and empty grains.

Optional Sorting: Color sorters may be used to ensure a uniform yellow color.
Final Cleaning: Includes washing the wheat to remove dust and dirt, though wastewater disposal can pose environmental challenges.

Importance of Cleaning: Proper cleaning prevents defects like burning or stickiness during bulguration and ensures a uniform, high-quality end product.

B. Bulguration (Cooking and Drying)

Bulguration combines cooking and drying stages, transforming cleaned wheat into bulgur. This is the most critical stage of production, as it involves significant changes in moisture and temperature.

Cooking:

Atmospheric Cooking: Wheat is boiled until starch is fully gelatinized, reaching 40–50% moisture content. The remaining water must be treated before disposal due to its high organic load.

Pressure Cooking: Soaking the wheat before high-pressure cooking reduces cooking time and improves nutritional quality by retaining water-soluble nutrients.

Cooling and Drying:

- Cooked wheat ("hedik") is cooled with ambient air to prevent stickiness.

Drying Stages:

- Initial drying in a rotary dryer prevents clumping.
- Final drying in tunnel dryers, typically with 8–10 stages, reduces moisture content to below 13%.
- Gradual temperature reduction (from 120–130°C initially) ensures uniform drying and prevents burning.

Challenges: Bulgur drying requires precise control of airflow, temperature, and humidity to avoid quality issues such as discoloration or incomplete drying.

C. Milling (Grinding) Operation

Milling transforms cooked and dried wheat into finished bulgur products of various sizes and qualities.

Steps in Milling:

Tempering: Soaking the kernels (15–30 minutes) to soften bran layers for efficient debranning.

Debranning: Removes bran using emery-type machines, improving the bulgur's texture and appearance.

Grinding: Roller or disc mills reduce the kernels to the desired particle size.

Polishing: A horizontal polisher rounds the edges of bulgur particles, giving them a brighter, more uniform appearance.

Classification:

Milled bulgur is classified into coarse, medium, fine, and ultra-fine categories, depending on its intended culinary use. These sizes are defined by national and international standards.

D. By-Products and Waste Management

By-Products: Includes bran, broken kernels, and bulgur flour, often used as animal feed.

Waste: Dust, stones, and metals are removed during cleaning; wastewater from cooking must be treated due to its environmental impact.

E. Future Directions

Bulgur production has potential for innovation, including:

- Development of new bulgur-like products using alternative grains or legumes.
- Enhancements in nutritional properties and sustainability.
- Modernization of production lines to preserve traditional flavor and taste during large-scale production.

Bulgur's versatility, nutritional value, and sustainable production methods make it a promising food product for future diets.

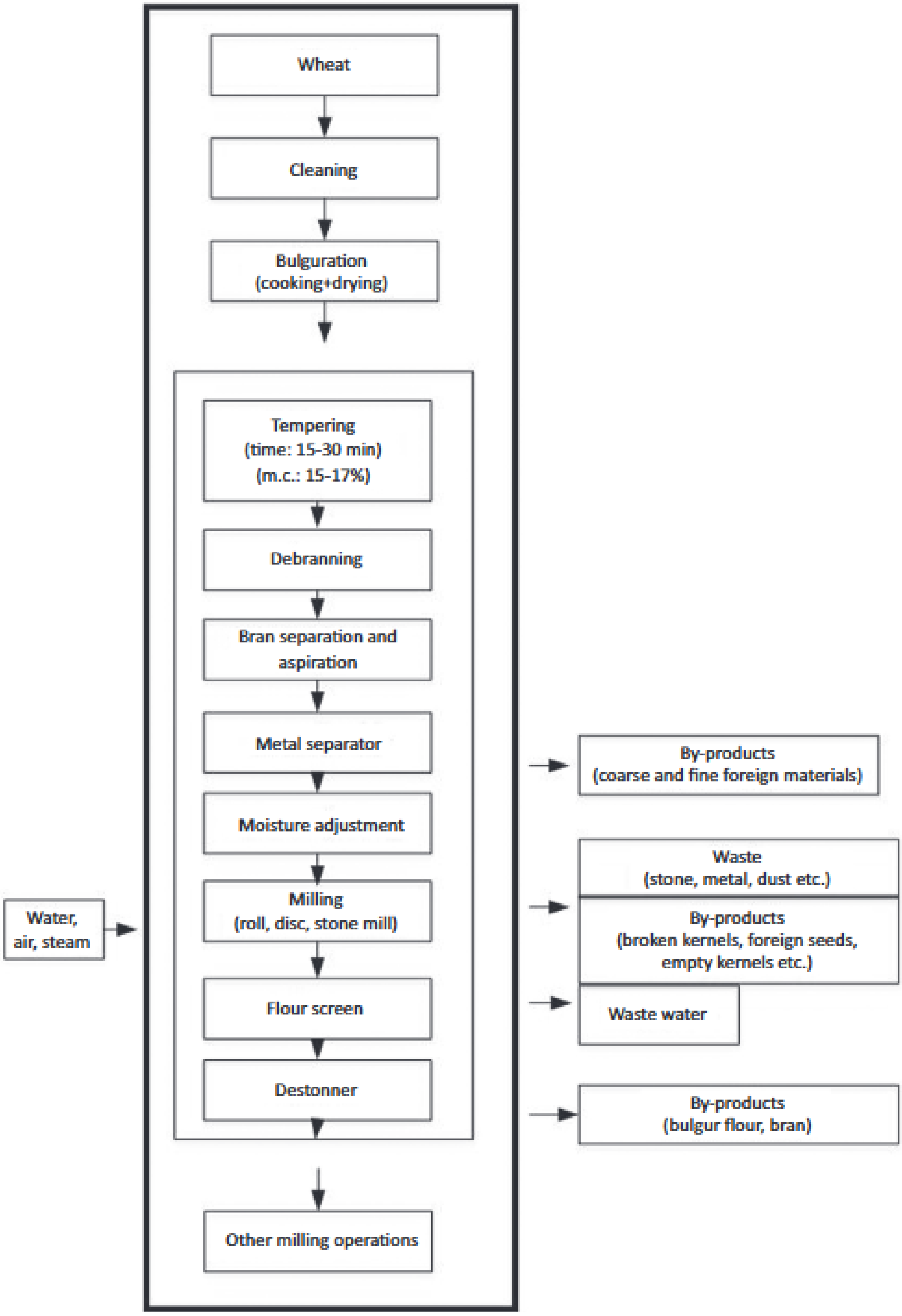

Figure 7 Bulgur production technology

1.4.1.3. Pasta Manufacturing Technology

Wheat semolina (from durum wheat) is hydrated, mixed, and extruded through dies to form various pasta shapes. Extrusion technology controls pressure, temperature, and shear forces to enhance texture and cooking properties.

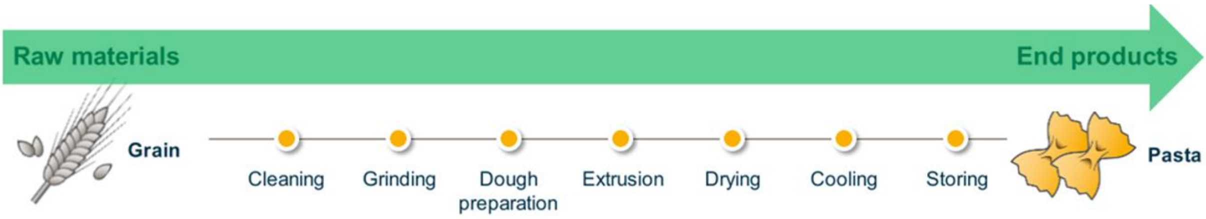

Figure 8 main steps of pasta manufacturing

Table 1 Comparison of nutritional properties of wheat, flour, durum and semolina

Constituent	Wheat	Flour	Durum	Semolina
Protein (Nx5.7) %	11.80	10.80	13.8	12.8
Ash %	1.50	0.40	1.50	0.80-1.10
Fiber %	4.60	0.10	4.60	2.90
Carbohydrate %	65.70	73.20	65.70	74.00
Fat %	2.30	1.10	2.30	1.50

Introduction

Pasta, available in both fresh and dry forms, is a globally popular food. Durum wheat (*Triticum durum Desf.*) is traditionally the preferred raw material for pasta production due to its unique protein rheological properties and vibrant pigment content. In countries like Italy, France, and Greece, national laws mandate the use of durum wheat semolina as the sole raw material for pasta production. Special pasta varieties, however, may include other cereals or ingredients, offering diverse compositions, colors, and shapes.

The production process involves creating a dough from semolina or flour, mixed with pure water and other ingredients, which is shaped through extrusion and dried under controlled conditions. This results in a durable product with a long shelf life. Industrial pasta production gained momentum in the 19th century with the advent of steam engines, hydraulic presses, and controlled drying systems. This chapter focuses on dry durum wheat pasta, emphasizing the importance of raw material quality, semolina production, and processing stages like kneading, extrusion, and drying.

Durum Wheat Quality for Pasta Making

Durum wheat is the preferred raw material for dry pasta production due to its hard, translucent, and flinty texture. The milling of durum wheat yields semolina, a granular endosperm product characterized by its bright yellow color. Durum wheat's suitability for pasta production is attributed to its protein composition and ability to form a strong gluten network that withstands kneading, extrusion, drying, and cooking.

Key Characteristics of Durum Wheat

Proximate Composition:

- Moisture: 12.0%
- Proteins: 13.0%
- Lipids: 2.9%
- Ash: 1.9%
- Dietary Fiber: 9.8%
- Carbohydrates: 60.4%

Protein Quality: Gluten proteins (gliadins and glutenins) comprise 80% of durum wheat proteins. These form a strong, elastic gluten network critical for pasta quality. Both protein quantity and composition influence pasta's cooking behavior.

Color: The yellow pigment in semolina, derived from carotenoids in the endosperm, influences pasta’s visual appeal. Processing factors like lipoxygenase activity during kneading or extrusion can degrade these pigments, affecting the final color.

Ash Content: Higher ash levels indicate higher bran content, affecting semolina yield and color. Millers seek durum wheat with low ash content for better semolina quality.

Kernel Size and Weight: Large, uniform kernels with high test weight are positively correlated with semolina yield.

Durum Wheat Milling for Pasta Making

The goal of durum wheat milling is to produce semolina with uniform granular particles, a bright yellow color, and minimal bran or specks. This semolina must withstand kneading and extrusion and retain its shape during drying and cooking.

Key Steps in Durum Wheat Milling

1. **Reception, Precleaning, and Storage**: Wheat grains are received, precleaned to remove debris, and stored in silos.
2. **Cleaning and Conditioning**: Impurities are removed, and moisture is added to soften the bran and improve milling efficiency.
3. **Grinding and Sifting**: Roller mills grind the wheat into semolina, which is sifted into various fractions by plansifters and purifiers.
4. **Debranning**: A modern step, debranning removes 6–10% of the outer bran layers using friction and abrasion, reducing ash content and specks.
5. **Final Milling Stages**:

   Break Passages (B): Kernels are broken down into semolina, flour, and bran.

   Detaching Passages (D): Bran particles are removed from the endosperm.

   Reduction Passages (RED): Fluted rollers refine semolina to uniform granulation for proper dough hydration.

Conversion Passages (C): Middling particles are processed into saleable flour with higher ash content.

Semolina Specifications

Moisture Content: 14.0–14.5%; risk of spoilage above 15.5%.

Granulation: Particle size varies between 200–600 μm, depending on pasta type.

Ash Content: Typically, below 0.9% for high-quality semolina.

Protein Content: Minimum 10.5% for standard pasta; 13.0% for premium quality.

Specks: Fewer than 200 specks per dm^2 ensures good visual quality.

Durum Wheat Dry Pasta Making

Pasta production involves several automated steps, including mixing, extrusion, drying, and packaging.

Mixing

Semolina and water are combined to form dough with a final moisture content of ~30%. Advanced mixing systems ensure uniform hydration and vacuum processing prevents oxidation, preserving color and flavor.

Extrusion

The dough is shaped using extrusion screws under high pressure, with water-cooling systems to maintain temperatures below 60°C. Dies (bronze or Teflon-coated) determine pasta shape and texture.

Drying

Fresh pasta (30% moisture) is dried to <12.5% moisture for stability. Drying involves:

1. **Predrying**: Reduces moisture to ~17–18%.
2. **Drying**: Utilizes controlled heat and ventilation.
3. **Humidification**: Balances internal and surface moisture.
4. **Cooling**: Stabilizes pasta for packaging.

Packaging

Pasta is weighed, packed into bags or boxes, and stored. Common materials include cellophane and paper.

Durum Wheat Dry Pasta Cooking and Nutritional Quality

Pasta's appeal lies in its sensory properties, nutritional value, and versatility. Cooking quality depends on semolina characteristics and the integrity of the gluten-starch network. High-gluten pasta remains "al dente," firm, and less sticky after cooking.

Nutritional Profile

Carbohydrates: 65%, with low glycemic impact due to pasta's dense structure.

Proteins: 13%, enhanced by pairing with animal proteins or legumes.

Fiber: Wholegrain pasta provides dietary fiber.

Vitamins and Minerals: A source of B vitamins and essential minerals.

Durum Wheat Dry Pasta Environmental Performance

The carbon footprint is a crucial measure for estimating the environmental impact of a product or activity. It represents the total greenhouse gases emitted, both directly and indirectly, during the production process, and is typically expressed in equivalent tons of CO_2. Calculating the carbon footprint involves a life cycle assessment, analyzing every stage of production and distribution to evaluate its environmental impact.

For 1 kg of dry pasta, the total carbon footprint is approximately **850 g CO_2 eq/kg**, from field to shelf. The breakdown is as follows:

- **Durum wheat cultivation**: 445 g CO_2 eq/kg (around 50% of the total footprint).
- **Milling**: 8 g CO_2 eq/kg.
- **Packaging**: 56 g CO_2 eq/kg.
- **Pasta production**: 252 g CO_2 eq/kg.
- **Distribution**: 91 g CO_2 eq/kg.

However, the cooking phase significantly increases the overall carbon footprint. Cooking pasta has an additional footprint of **784 to 2100 g CO_2 eq/kg**, depending on whether gas or electricity is used.

To reduce the environmental impact of dry pasta, focus should be placed on:

1. **Sustainable cultivation practices** for durum wheat to minimize agricultural emissions.
2. **Optimizing cooking methods**, such as adjusting the water-to-pasta ratio, using passive cooking techniques, or improving energy efficiency during cooking.

By addressing both production and cooking practices, the carbon footprint of pasta can be significantly lowered.

1.4.2. Rice Processing Technology

Figure 9 Rice

Staple Products: Polished rice, rice flour, puffed rice, and gluten-free baked goods.

Polished Rice Production

The production of polished rice involves the removal of the husk and bran layers from raw rice to produce smooth, white kernels. This is achieved through a sequence of steps starting with dehusking machines, which remove the outer husk, followed by polishing machines that scrape off the bran and germ layers. Precision is critical during polishing to maintain grain quality while minimizing breakage and nutrient loss. Innovations in polishing machine design, including automated controls, allow for higher efficiency and improved rice quality, catering to consumer preferences for texture and appearance.

Puffed Rice

Puffed rice is created by subjecting parboiled rice to high-pressure steam, followed by a rapid pressure release. This abrupt change causes the internal moisture to vaporize instantly, puffing and expanding the grains. The process requires controlled conditions in puffing chambers, with specific attention to temperature and pressure to achieve uniformity in size, texture, and crispness. This technology is integral to the production of light, crispy snacks and breakfast cereals, widely consumed around the world.

Rice-Based Gluten-Free Products

Rice serves as a cornerstone ingredient in gluten-free food products due to its natural lack of gluten. Rice flour is used to create gluten-free bread and cookies, providing a neutral flavor and desirable texture. Modified rice starch, derived from treated rice flour, is a key component in soups and sauces, acting as an effective thickener and stabilizer. These rice-based products cater to the dietary needs of individuals with gluten intolerance, offering both functionality and versatility in various culinary applications.

1. **Cleaning**: The initial step involves removing impurities such as stones, dust, and chaff from the paddy to ensure the quality of the final product.
2. **Husking (Dehusking)**: This process removes the husk (outer shell) from the paddy grains, resulting in brown rice.
3. **Paddy Separation**: Unhusked paddy is separated from the brown rice. The unhusked grains are returned to the husking process for further treatment.
4. **Whitening (Polishing)**: The bran layer is removed from the brown rice to produce white rice. This step may involve multiple stages to achieve the desired level of whiteness.
5. **Grading**: The milled rice is sorted based on size and quality, separating whole grains from broken ones.
6. **Packaging**: The final product is packed for distribution and sale.

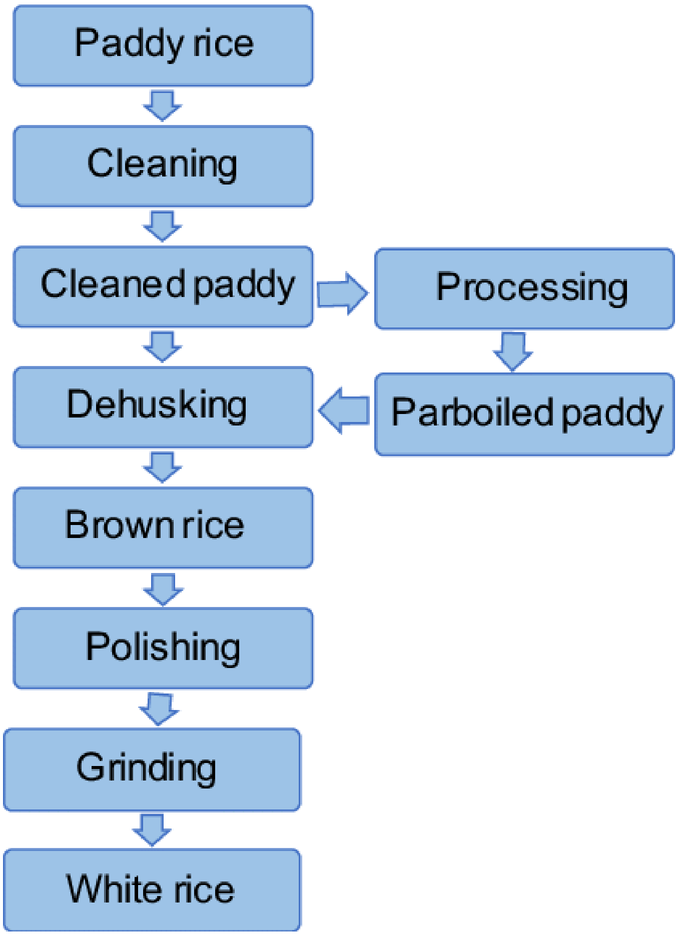

Figure 10 Rice production steps

1.4.3. Barley Processing Technology

Staple Products: Malt for brewing, health foods, and soups.

Malt for Brewing

Malt is a key ingredient in beer production, created through a multi-step process involving steeping, germination, and kiln-drying of barley grains. In the steeping stage, barley grains are soaked in water to reach the optimal moisture content for germination. Germination follows, during which enzymes like amylase are activated to convert the grain's starches into fermentable sugars. Finally, the germinated barley is kiln-dried to halt enzyme activity and develop the characteristic flavors of malt.

Precise control of germination conditions, including temperature and moisture levels, is critical to optimize enzyme activity and ensure high-quality malt. Engineering advancements in germination chambers and kiln systems allow for consistent results and scalability. Malt produced through this process is integral to beer production, contributing to its flavor, color, and alcohol content.

Barley in Health Foods

Barley is increasingly utilized in health-focused foods due to its high content of beta-glucan, a soluble dietary fiber known for its cholesterol-lowering and heart health benefits. High beta-glucan barley flour is used in baked goods, breakfast cereals, and snack products to enhance their fiber content.

Air classification technology is employed to efficiently separate high-fiber fractions from barley. This method uses air streams to stratify and collect different components based on their size and density, enabling the production of enriched barley flours with targeted nutritional profiles. Such innovations not only support the development of functional foods but also align with growing consumer demand for healthier dietary options.

The malting process transforms barley into malt, a key ingredient in brewing, through several stages:

1. **Milling**: The malted barley is crushed to expose starches for conversion.
2. **Mashing**: Crushed barley is mixed with hot water to convert starches into fermentable sugars, creating wort.
3. **Lautering**: The liquid wort is separated from solid barley husks.
4. **Boiling**: The wort is boiled, and hops are added for flavor, bitterness, and aroma.
5. **Whirlpool**: Solids (like hop particles) are removed from the wort.
6. **Chilling**: The wort is cooled to prepare for fermentation.
7. **Fermentation**: Yeast is added, converting sugars into alcohol and CO2.
8. **Maturation**: The beer is aged for flavor development.
9. **Packaging**: The beer is packaged for distribution and consumption.

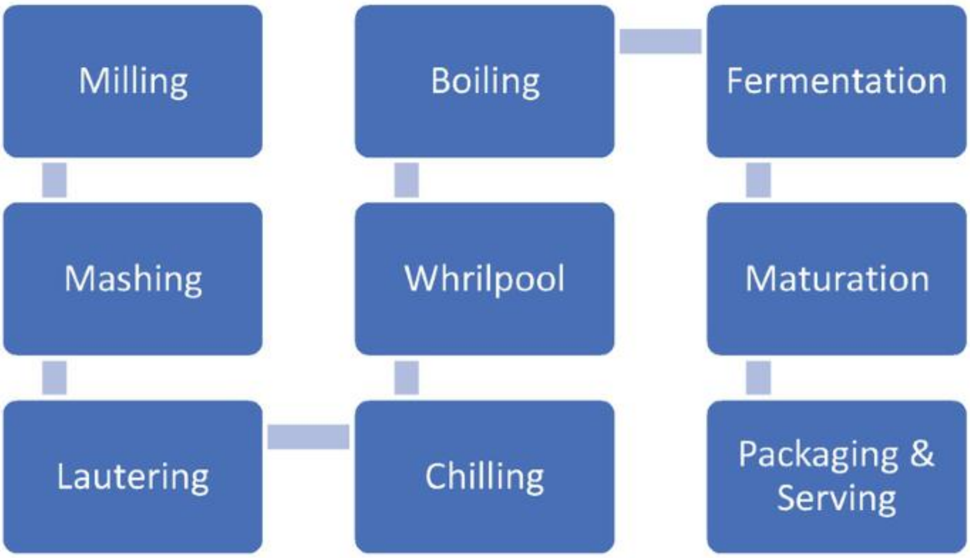

Figure 11 Malting process

1.4.4. Maize (Corn) Processing Technology

Cornmeal and Tortillas: Corn kernels are ground into flour or treated with lime (nixtamalization) to make dough for tortillas. Technologies optimize cooking and grinding to ensure dough elasticity and flavor.

Corn Syrup: Corn starch is broken down using enzymes to produce glucose syrup, or further processed into high-fructose corn syrup using isomerization. Advanced filtration and continuous reactors are key here.

Snacks: Corn is turned into chips or puffed snacks using **extrusion technology**, where heat and pressure create light, crispy products.

1.4.5. Oat Processing Technology

Oat processing for staple products like breakfast cereals and instant oatmeal involves specific techniques to ensure quality and convenience. For breakfast cereals, oat groats are steamed, rolled into flakes, and toasted. This process often includes adding sugar or flavorings to enhance taste. Controlling heat and moisture during rolling and toasting is crucial for uniformity and extended shelf life. For instant oatmeal, the oats are pre-cooked, dried, and finely ground to enable quick hydration. This process utilizes rapid steam cooking systems, which are designed to preserve nutrients while reducing preparation time. These technologies ensure that oat-based products meet consumer expectations for taste, convenience, and nutritional value.

Figure 12 Oat

1.5. Cereal Processing Machines and Technologies

1.5.1. Cleaning Equipment

Optical Sorter

An optical sorter removes discolored, defective, or non-uniform grains to ensure consistency and quality. Using advanced cameras and LED technology, it identifies and rejects grains deviating from desired characteristics, ejecting them with pneumatic nozzles. This technology is vital for improving both aesthetic and intrinsic product value, particularly for premium cereals like rice, durum wheat, and lentils, where visual quality greatly impacts market value.

Magnetic Separator
A magnetic separator is designed to remove metallic impurities from raw cereals. It works by passing grains through a magnetic field, capturing ferrous and non-ferrous metals to prevent contamination of the final product and protect downstream machinery. This equipment is crucial in initial cleaning stages, particularly in flour and feed mills, where metallic debris might be present due to harvesting or transportation.

Grain Cleaner
Grain cleaners remove dust, stones, shriveled grains, and other foreign materials. These machines often use vibrating sieves, aspiration systems, and rotating screens to classify grains by size, weight, and density. Critical for preparing cereals for further processing, grain cleaners ensure only clean grains are used, enhancing the efficiency and output of subsequent operations.

Destoner
A destoner separates stones and other dense impurities from cereals. By employing vibrating decks and airflow to utilize density differences, it ensures only grains proceed to subsequent stages. Commonly used in wheat and rice processing, destoners enhance safety by preventing stone-induced equipment damage and maintaining product quality.

1.5.2. Conditioning Equipment

Tempering Tanks and Systems
Tempering tanks add moisture to grains, softening the bran and toughening the endosperm for easier separation during milling. This process is essential in wheat and durum processing, as it improves milling efficiency and product yield. Consistent hydration achieved during conditioning is critical for ensuring the quality of the final product.

1.5.3. Milling Equipment

Roller Mills
Roller mills, equipped with fluted and smooth rollers, are used to break grains into smaller fractions and grind the endosperm into flour or semolina. The milling process includes multiple stages, with break rolls separating bran and endosperm and reduction rolls refining the particle size. Roller mills are fundamental to determining granulation, texture, and the quality of flour and semolina.

Plansifters
Plansifters separate milled products into different particle sizes using a stack of vibrating sieves. They stratify materials, directing finer particles to collection channels

and coarser particles to additional processing. Plansifters are indispensable in flour and semolina plants, ensuring uniform granulation and consistent product quality.

Purifiers
Purifiers clean semolina by removing bran particles through sieving and aspiration. Essential in durum wheat milling, purifiers refine the texture and color of semolina, a key ingredient in pasta production. This step ensures high-quality semolina suitable for demanding applications.

1.5.4. Auxiliary Milling Equipment

Impact Detachers
Impact detachers break flour flakes formed during grinding, ensuring uniform particle distribution. By minimizing waste, this technology increases flour yield and plays a vital role in achieving high milling efficiency.

Bran Finishers
Bran finishers extract residual flour from bran-rich material through mechanical action. This equipment maximizes flour recovery and reduces waste, contributing significantly to the economic efficiency of milling operations.

Vibro Sieves and Control Sieves
Vibro sieves and control sieves perform fine separation of unwanted materials or oversized particles across various milling stages. They enhance product uniformity and operational hygiene, ensuring consistent output quality.

1.5.5. Drying Equipment

Rotary and Tunnel Dryers
Rotary dryers are used in bulgur production to pre-dry sticky kernels, preventing clumping. Tunnel dryers, on the other hand, ensure controlled, uniform drying at different temperature stages. Both technologies are critical for microbial safety, extended shelf life, and maintaining the structural integrity of cereal products.

Continuous Dryer
Continuous dryers reduce moisture in products like pasta or bulgur to ensure shelf stability and microbial safety. Using controlled airflow, temperature, and humidity, they maintain the structural integrity and quality of the final product. These dryers are commonly used in dry pasta and ready-to-eat cereal production.

1.5.6. Storage and Conveying Systems

Aerated Silos
Aerated silos store clean and conditioned grains under controlled conditions, protecting them from spoilage due to pests or mold. These silos are vital for maintaining grain quality until it is processed.

Pneumatic Conveyors
Pneumatic conveyors transport cereals and flour hygienically using air pressure systems. Their use minimizes contamination and improves operational efficiency, especially in automated high-capacity plants.

1.5.7. Automation and Control Systems

Moisture Controller
Moisture controllers regulate the water content in grains during stages like tempering, milling, or drying. Sensors measure moisture levels, adjusting water addition or drying parameters to ensure consistency. This technology is vital for preventing over- or under-processing and ensuring the quality of the final product.

PLC-Based Systems
Programmable Logic Controller (PLC)-based systems monitor and control milling operations, providing real-time data on production parameters and enabling automated adjustments. These systems ensure consistent product quality, reduce human error, and improve operational efficiency.

Flow Balancers and Yield Control
Flow balancers and yield control devices optimize grain and product flows during milling. By improving consistency and reducing waste, they enhance economic efficiency and ensure that production targets are met without compromising quality.

FE 401 Food Technology

Dr. Fatih BALCI

Starch Technology and Syrup Production

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Content

1. **Starch Composition and Gelatinization**

1.1. Starch: An Overview of Its Role and Importance

Plants store the energy obtained through photosynthesis as **starch**, primarily in seeds, stems, and tubers. This type of starch, known as **storage starch**, serves as a significant energy reserve and is widely utilized for food and industrial applications. Among cereal grains, starch content constitutes a substantial portion of the grain weight, varying between **60% to 75%** depending on the type of cereal. For example:

- **Wheat** contains approximately **65% starch**.
- **Maize (corn)** has about **70% starch**.
- **Rice and rye** contain roughly **60% starch**.

Starch in the Human Diet

Starch is a key **dietary carbohydrate**, acting as a major source of energy. During digestion, starch is metabolized into glucose, providing a readily available energy supply for the human body. Beyond its nutritional value, starch plays a crucial role in determining the **physical properties** of many food products:

a) **Gelling and Thickening**:
   i) Starch is responsible for the gelling properties of puddings and porridges.
   ii) It provides the desired consistency in sauces and soups.
b) **Bread Structure and Staling**:
   i) In bread, starch helps form the structural framework during baking.
   ii) Retrogradation of starch during storage contributes to **staling**, leading to firmer and less palatable bread.
c) **Texture of Cakes**:
   i) Starch plays a vital role in **structure formation** in baked goods like cakes, influencing their crumb and moisture retention.

Industrial Applications of Starch

Apart from its use in food, starch is a valuable **industrial raw material**, with applications extending to several fields:

Starch-Based Syrups: Starch is hydrolyzed to produce sweeteners like **glucose syrup**, widely used in soft drinks, candies, and baked goods.

Paper Industry: Starch is utilized as a binder and coating agent in **paper production**, enhancing surface quality and printability.

Bioethanol Production: As a renewable energy source, starch is fermented to produce **bioethanol**, a sustainable alternative fuel.

Starch is indispensable both as a **nutrient** and as an **industrial resource**. Its dual role—providing energy in the diet and serving as a versatile material in numerous industries—underlines its significance in modern life. From the breakfast table to energy production, starch is a cornerstone of human consumption and technological innovation.

1.2. Introduction to Starch Composition

Starch is a polysaccharide stored in plants and serves as their primary carbohydrate reserve. Found abundantly in cereal grains, tubers, and legumes, starch is composed of two key polymers: amylose and amylopectin. These components differ significantly in structure, molecular weight, and functional behavior, influencing how starch behaves in food systems.

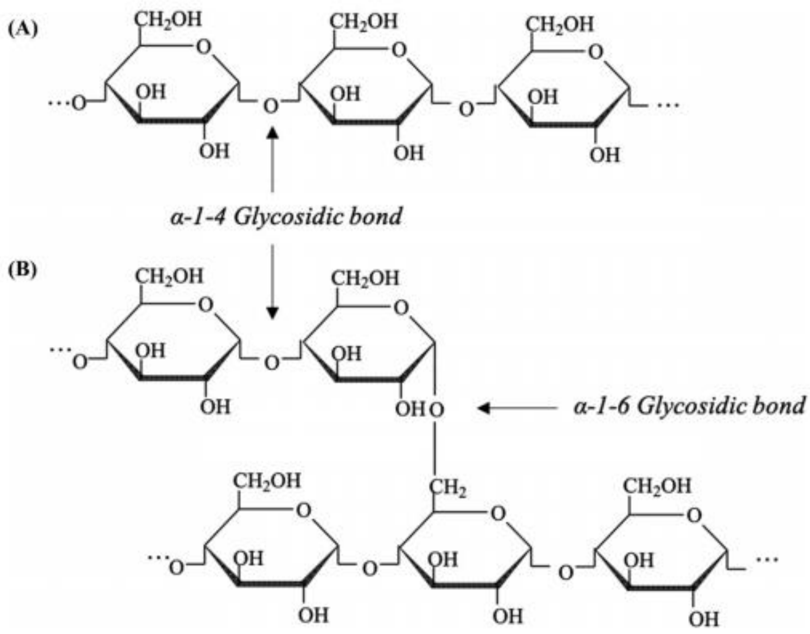


Figure 1. Chemical Structure of amylose (A) and amylopectin (B)

Amylose is a mostly linear polymer made of α-D-glucose units connected by α-1,4 glycosidic bonds. Its linear nature allows it to form helical structures, which can interact with iodine to produce a characteristic blue color. Amylose has a relatively small molecular weight compared to amylopectin but plays a crucial role in gel formation, contributing to the firmness of starch-based gels.

Amylopectin, in contrast, is a highly branched polymer with α-1,4 glycosidic bonds forming its linear chains and α-1,6 bonds at the branch points. This branching makes amylopectin much larger than amylose and contributes to its ability to provide viscosity rather than gelation. Starch with higher amylopectin content is preferred in applications requiring thickening, such as sauces and gravies, while high-amylose starch is suitable for products needing firmer textures, such as films and certain confectioneries.

1.3. Gelatinization of Starch

Gelatinization is the process by which starch granules absorb water, swell, and lose their crystalline structure when heated. At the molecular level, this involves the breaking of hydrogen bonds within the starch granule and the disruption of the ordered crystalline regions.

Initially, when starch is mixed with water and heated, water molecules penetrate the amorphous regions of the granule. As the temperature rises, the granules swell, and the birefringence—visible under polarized light as a Maltese cross—begins to disappear. At this stage, amylose starts leaching out into the surrounding water, while the granules continue to absorb more water, increasing in size. This transformation is irreversible and marks the gelatinization process.

The gelatinization temperature varies between starches from different sources. For instance, wheat, barley, and rye gelatinize at relatively low temperatures, typically between 52°C and 65°C. Starches like maize and sorghum gelatinize at higher temperatures, often exceeding 70°C. These properties make starches versatile in food applications, such as thickening soups and stabilizing emulsions in salad dressings.

1.4. Retrogradation of Starch

Retrogradation occurs when gelatinized starch molecules realign themselves into more ordered structures upon cooling. This phenomenon primarily involves the linear amylose molecules, which form double helices and eventually crystallize. Amylopectin retrogradation is slower due to its branched structure, but it becomes significant over longer storage periods.

In food systems, retrogradation has both desirable and undesirable effects. In bread, for example, retrogradation is responsible for staling, where the texture becomes hard, and water is expelled from the starch network—a phenomenon known as syneresis. On the other hand, controlled retrogradation is used to produce resistant starch, a form of dietary fiber beneficial for gut health. Retrogradation can also enhance the texture of foods like rice or pasta, making them firmer upon cooling.

1.5. Starch Production Technology

Industrial starch production involves several key steps, which vary depending on the source material—common sources include corn, wheat, potato, and cassava.

The process begins with cleaning, where foreign materials such as dust and stones are removed to ensure product quality. In the case of corn, steeping follows, during which kernels are soaked in water to soften the grains and loosen the starch. This step also aids in separating other components like protein and fiber. The softened grains are then milled to break down the structure, releasing starch granules.

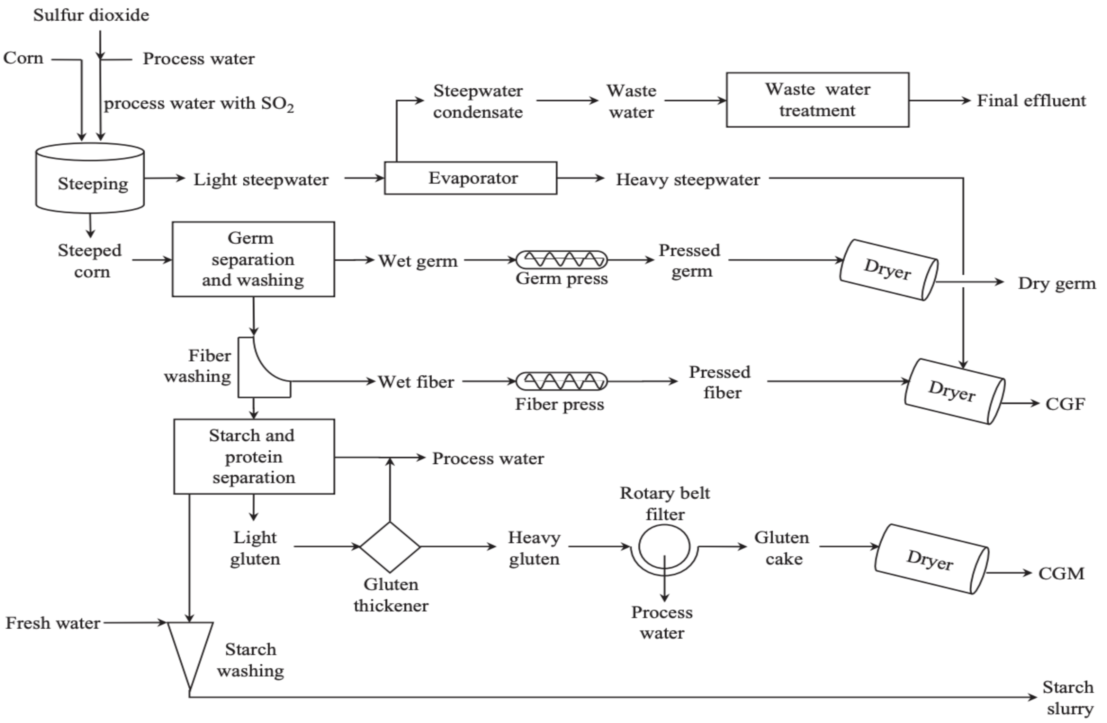


FIG. 18.1 Wet milling process flow diagram (Rausch et al. 2005, 2007).

Steps of Starch Production from Corn

Corn is the primary raw material for starch production due to its high starch content and abundance. The production process involves several stages designed to extract and purify starch while separating valuable by-products like oil, protein, and fiber. Below is a detailed breakdown of the steps:

1. Cleaning

The corn kernels are thoroughly cleaned to remove impurities such as dirt, stones, metals, and other foreign materials. Cleaning involves sieves, magnets, and aspirators to ensure high-quality raw material for processing.

2. Steeping

Steeping is a critical step where corn kernels are soaked in warm water (50–60°C) for 30–48 hours in large steeping tanks. Sulfur dioxide is typically added to the water to prevent microbial growth and loosen the corn structure. Ideal steep water should contain SO_2 between 1200-1400 ppm.

Purpose

- Softens the kernels.
- Swells the starch granules.
- Begins the separation of components like protein and fiber.
- Extracts soluble nutrients into the steep water (used later in animal feed production).

3. Milling (Grinding)

After steeping, the softened kernels are coarsely ground to break them open and release the germ.

4. Germ Separation: The ground mixture passes through hydrocyclones or germ separators, where the lighter germ (rich in oil) is separated. The germ is then processed further to extract corn oil.

FIG. 18.7 Battery of hydrocyclones used for separation of germ from milled steeped corn. *(Courtesy of Dorr-Oliver, Inc., Stamford, Connecticut.)*

4. Fine Milling

The remaining material, mostly starch, fiber, and protein, undergoes fine grinding to release starch granules from the protein matrix and fibers.

5. Fiber Separation

The slurry is passed through screens and hydrocyclones to separate the coarse fiber.
By-Product: The fiber is dried and used as an ingredient in animal feed.

6. Starch-Protein Separation

The fine slurry, containing starch and protein, is directed to centrifuges or hydrocyclones for separation based on density.

- Starch, being denser, is separated as a "starch milk."
- Protein (commonly called "corn gluten") is separated as a lighter fraction.
- **By-Products**: Corn gluten is used in animal feed and as a source of protein in aquaculture feed.

With the germ and fiber separated from the ground corn slurry, known as millstarch, the bulk of the starch and high-protein substances of gluten plus a small amount of soluble corn impurities remain. The gluten is separated from the starch by taking advantage of the lower density of gluten (1.06 g/cm3 in contrast to 1.6 g/cm3 for starch).

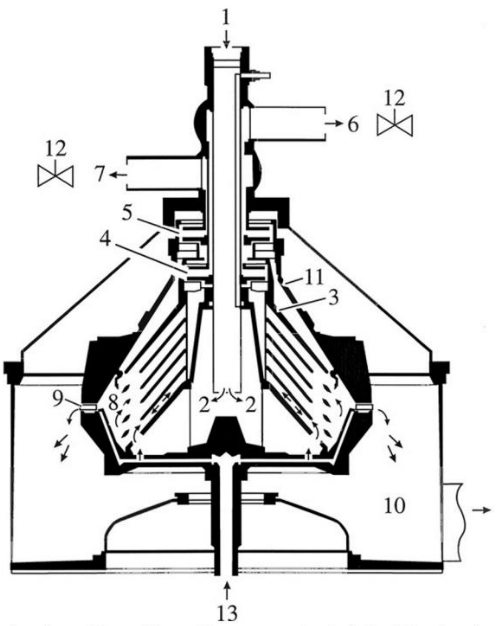


FIG. 18.9 Cut-away diagram of a nozzle-bowl centrifuge with washing system. 1 = feed; 2 = inlet chamber for product; 3 = disc stack; 4 = centripetal pump, light phase; 5 = centripetal pump, medium phase; 6 = discharge, medium phase; 7 = discharge, light phase; 8 = concentrate chamber; 9 = nozzles; 10 = concentrate catcher; 11 = separating disc; 12 = throttle; and 13 = feed, wash water. *(Courtesy of GEA Westfalia Separator AG, Oelde, Germany.)*

7. Starch Washing

The starch milk is washed multiple times to remove residual protein and other impurities. High-purity starch is achieved through repeated washing with water in hydrocyclones or centrifuges. The crude starch is washed with fresh water in countercurrent fashion, using hydrocyclones that are 10mm diameter and grouped into clusters enclosed in housings capable of holding as many as 720 cyclones.

FIG. 18.10 A starch washing hydrocyclones. *(Courtesy of the Center for Crops Utilization Research, Iowa State University.)*

These units are then arranged into 10–14 separate stages operating in series. This is more than the 6–8 stages required to wash.

FIG. 18.11 Hydrocyclone starch washing and starch separating units. Each clamshell contains as many as 480 individual hydrocyclone tubes 10mm in diameter. *(Courtesy of Dorr-Oliver, Inc., Stamford, Connecticut.)*

The efficiency of a hydrocyclone depends on pressure decrease across the unit, control of the underflow orifice, input solids concentration, and particle and fluid properties. About 2.1–2.5L of fresh water/kg of dry starch is used to extract soluble impurities in the starch, and the hydrocyclone action mechanically separates the remaining insoluble gluten.

Water used for starch washing is the primary demand for fresh water by the process and generally is deionized. It can be supplemented with a suitably pure condensate from within the plant. The water is heated to 38–43°C (100–110°F) to enhance separation of soluble matter. The lower temperature currently is more prevalent because more stages of hydrocyclones are being used and more heat is generated from the additional pumps. Temperature sensors in the hydrocyclone systems protect the starch slurry from temperatures exceeding 54°C (129°F), well below starch gelatinization temperature of 63°C (145°F). A heat exchanger usually is placed midway through the starch washing hydrocyclone battery to remove excess heat.

Starch washing employs countercurrent water usage. The wash water enters the washing system at the last stage, where washed starch is exiting. In each stage, overflow is routed to the preceding stage and underflow advances to the next stage. To wash starch to acceptable residual protein levels (0.3%–0.5%, depending on the type of corn) requires the proper amount of wash water. That amount of wash water is inversely proportional to the number of washing stages. With the normal eight to 14 stages of hydrocyclones, the wash water ratio would be 3.0–2.1L water/kg starch, respectively.

8. Dewatering and Drying

The purified starch is dewatered using vacuum filters or decanters to remove excess water. The starch is then dried using starch peeler or spray dryers to reduce the moisture content to 10–12%, resulting in powdered starch.

Figure. Starch peeler centrifuge

9. Packaging and Storage

The dried starch is sieved to ensure uniform particle size and packed in moisture-proof bags. It is stored in controlled environments to prevent moisture absorption or contamination.

By-Products Utilization

The corn wet-milling process generates several valuable by-products:

1. **Corn Germ**: Processed into corn oil.
2. **Corn Gluten**: Used in animal feed.
3. **Corn Fiber**: Utilized as roughage in feed.
4. **Steep Water**: Concentrated into a nutrient-rich liquid feed additive.

Separation of starch from other components is achieved using centrifugal or hydrocyclone techniques. These processes exploit the density differences between starch and other solids, yielding a purified starch slurry. The final step involves drying, where the slurry is dewatered using vacuum filters or spray dryers to produce powdered starch.

Modified starches are produced by subjecting native starch to physical, chemical, or enzymatic processes. For instance, cross-linked starches are treated with reagents like phosphorus oxychloride to enhance stability under high temperatures and acidic conditions, making them suitable for pie fillings. Pregelatinized starch is created by partially cooking the starch and then drying it, enabling it to thicken without heating, as seen in instant pudding mixes.

1.6. Sustainability in Starch Production

The traditional starch production process is resource-intensive, requiring significant water and energy inputs. However, advancements in sustainable technologies aim to mitigate these challenges.

Closed-loop systems are being increasingly adopted to recycle process water, reducing overall water consumption. Additionally, byproducts such as bran, husk, and protein can be valorized into animal feed, biofuels, or even as functional food ingredients. Enzyme-assisted extraction techniques are also gaining popularity as they improve yield and purity while reducing energy requirements. For example, using amylases in cassava starch extraction has been shown to reduce processing time and environmental impact.

1.7. Applications in Food Technology

Starch plays a critical role in food systems, serving as a thickener, stabilizer, and texturizer. In bakery products, starch enhances dough handling and contributes to the crumb structure. In dairy alternatives, it provides the creamy texture and stabilizes emulsions. Modified starches extend the range of applications, such as improving freeze-thaw stability in frozen foods and creating clear, viscous sauces in acidic conditions.

Emerging technologies, such as nanotechnology, are opening new avenues for starch applications. For instance, starch-based nanoparticles are being developed for the encapsulation of flavors, nutrients, and bioactive compounds, enhancing their stability and delivery in functional foods.

1.8. Summary

Starch is a versatile carbohydrate polymer essential in food production. Its two main components, amylose and amylopectin, dictate its behavior in processes like gelatinization and retrogradation. Industrial production of starch involves cleaning, steeping, milling, separation, and drying, with modifications to tailor its functionality. Sustainability in starch processing is increasingly important, with innovations aimed at reducing water and energy use. Applications of starch in food systems range from thickening soups to creating gluten-free baked goods, highlighting its critical role in food technology.

2. Enzymatic Hydrolysis of Starch

Starch, composed of glucose units linked by glycosidic bonds, is an excellent substrate for enzymatic hydrolysis, leading to the production of glucose syrups, also referred to as glycose syrups. The extent of hydrolysis is quantified by the **Dextrose Equivalent (DE)** value, which represents the percentage of glycosidic bonds hydrolyzed. The DE value is a critical factor influencing the functional properties of syrups, such as sweetness, solubility, viscosity, water-binding capacity, gelling behavior, and hygroscopicity. Industrially, syrups are categorized based on their DE values into low-DE (20–40), standard-DE (42), medium-DE (48–58), and high-DE (60–95) syrups. High-DE syrups are particularly valued for their low viscosity, high solubility, intense sweetness, and better water-binding and fermentability compared to low-DE syrups.

The production process for glucose syrups begins with the gelatinization of starch. Gelatinization involves heating starch with water and acid to disrupt the crystalline granule structure, making the starch paste less viscous and more amenable to enzymatic hydrolysis. After gelatinization, specific **starch-degrading enzymes** are employed to hydrolyze the starch into syrups of varying DE values, depending on the intended application. These enzymes belong to the **glycoside hydrolases (GH)** family, which includes both **endoenzymes** (cleaving internal glycosidic bonds) and **exoenzymes** (cleaving bonds at the non-reducing ends of the starch chain).

One of the key enzymes in this process is **α-amylase**, an endoenzyme that hydrolyzes α-1,4 glycosidic bonds within the starch molecule but cannot break the α-1,6 branch points. Its action produces syrups with relatively low DE values (10–25). Industrially, bacterial and fungal α-amylases are used, with bacterial enzymes operating at higher temperatures (100–110°C) and fungal enzymes at moderate temperatures (55–60°C). **β-Amylase**, another enzyme used in starch hydrolysis, acts as an exoenzyme, progressively removing maltose units by hydrolyzing the α-1,4 bonds from the non-reducing ends of starch molecules. When combined with α-amylase, β-amylase enhances hydrolysis efficiency, producing maltose-rich syrups with DE values of 40–45.

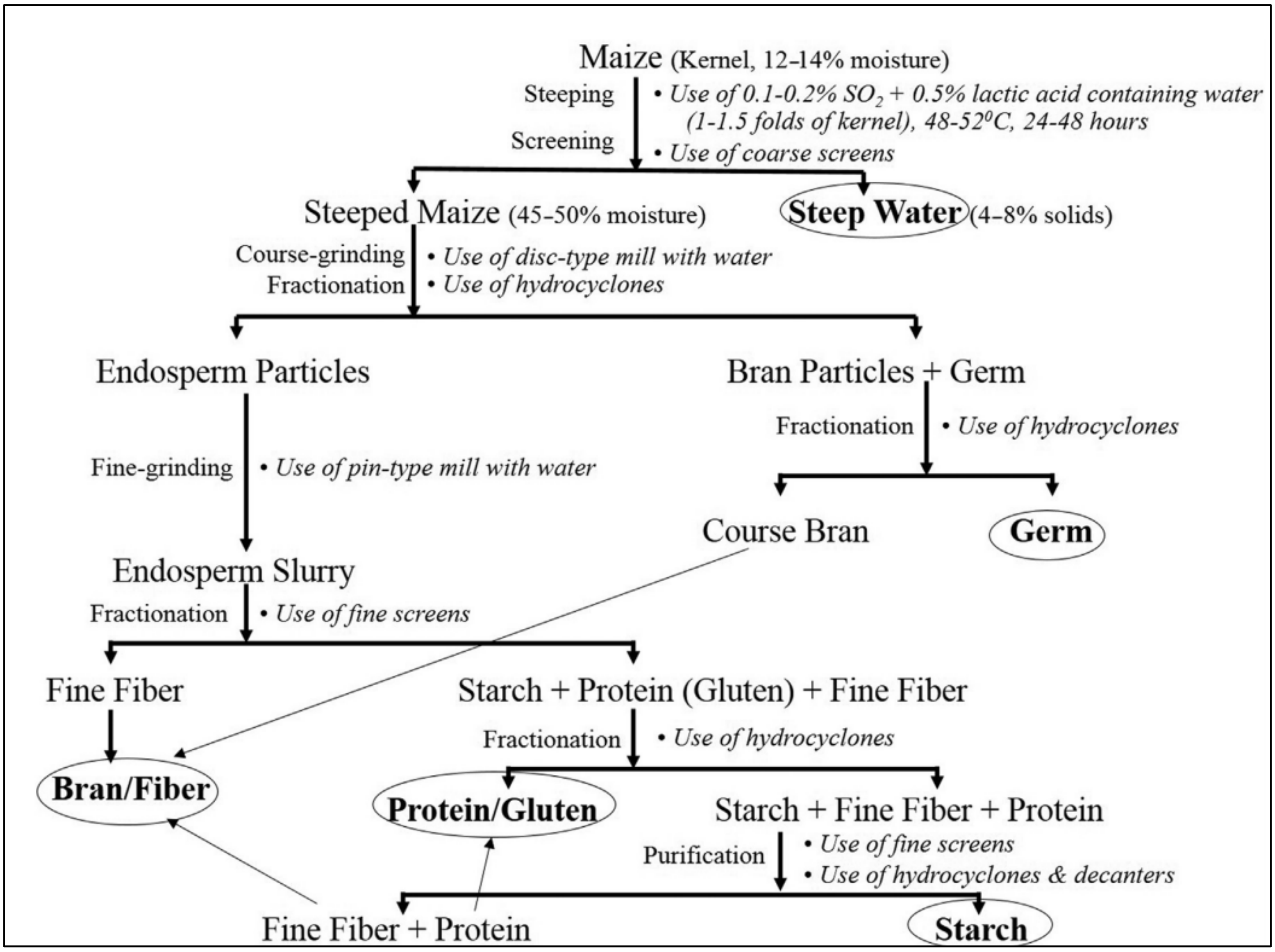
Glucoamylase (amyloglucosidase) is an exoenzyme capable of hydrolyzing both α-1,4 and α-1,6 glycosidic bonds, although it works faster on α-1,4 bonds. It acts on the non-reducing ends of starch molecules, breaking them down completely into glucose. This enzyme is particularly useful for producing syrups with high DE values, reaching up to 95, which makes them ideal for applications requiring high sweetness and solubility.

To address the branch points in amylopectin, **debranching enzymes** like pullulanase and isoamylase are employed. These enzymes specifically hydrolyze α-1,6 bonds, breaking down the branched structure of starch and allowing for more efficient hydrolysis. When used in combination with glucoamylase, these debranching enzymes produce syrups with very high DE values (90–95), suitable for specialized industrial uses. Additionally, **glucose isomerase** is employed to convert glucose into fructose, yielding high-fructose corn syrup (HFCS). HFCS is sweeter than glucose syrups and is widely used in soft drinks and processed foods due to its intense sweetness and functional properties. Enzymatic hydrolysis of starch thus offers a highly versatile pathway for producing syrups with tailored properties to meet specific industrial requirements. These syrups are extensively used in food, beverages, and fermentation industries, underscoring the importance of enzymatic starch conversion in modern food technology and industrial processes.

3. Corn Processing: Milling Technologies

Corn processing employs two primary milling methods: **dry milling** and **wet milling**. The choice of method depends on the desired end products and their applications. **Dry milling** is predominantly used in the food industry to produce high-quality grits, flour, and corn germ. The main objective of dry milling is to separate the kernel's primary components—germ, bran, and endosperm—and further process the endosperm into valuable food products. In contrast, **wet milling** is used primarily for industrial purposes, where the focus is on extracting starch and other fractions, including protein, fiber, and germ, for diverse applications such as food additives, bioethanol production, and animal feed.

Maize, the leading cereal crop globally, produces approximately 1.1 billion metric tons annually. **Dent-type maize** is the most suitable for wet-milling, accounting for about 80% of the total maize production. Other varieties include flint, pop, and sweet maize. Wet-milling represents approximately 10% of global maize utilization, with the rest primarily



used for feed, fuel ethanol, food, and seed. This process is designed to separate maize kernels into their main components: starch, germ, protein, fiber, and water.

3.1. Quality Parameters for Wet-Milling

The quality of maize significantly impacts the efficiency and output of wet-milling. Factors such as maize type, kernel size, hardness, starch content, and postharvest treatments influence the milling process. Dent-type hybrids with large, sound, homogeneous kernels are preferred due to their higher starch content and softer kernels, which facilitate processability. Kernels with low-to-medium hardness minimize starch-protein interactions, reducing steeping time and improving starch yield.

Careful postharvest handling is essential. Exposure to excessive temperatures (above 75°C) during drying can create internal cracks in the kernels, increasing solid losses during steeping and strengthening starch-protein interactions, which lowers wet-milling efficiency. Proper drying, storage, and transportation are vital to maintain kernel quality.

3.2. Industrial Wet-Milling Process

Figure 2. Flow diagram of conventional process for wet milling of maize

The **wet-milling process** is an established bicentennial method consisting of several key stages:

A. Steeping

The cleaned maize kernels are steeped in a series of bins (each with a capacity of 100–500 metric tons) containing water at 1.0–1.5 times the weight of maize. The steeping solution is maintained at 48°C–52°C and contains **0.1%–0.2% sulfur dioxide (SO_2)** and **0.5% lactic acid**. The water should not exceed 55°C (131°F) to avoid inactivating the Lactobacillus flora and reducing or eliminating production of lactic acid. A steep kept at temperatures above 55°C could gelatinize some of the starch granules or may produce acetic acid (Acetobacter bacteria), producing a vinegar odor. Steeps held at temperatures below 45°C will favor yeast growth and have odors similar to yeast or ethanol.

Steeping softens the kernels, facilitates the diffusion of SO_2 into the endosperm, and breaks down starch-protein and bran-endosperm interactions. SO_2 serves multiple functions, including solubilizing maize gluten proteins, acting as an antioxidant, and protecting against microbial spoilage. After 30–48 hours of steeping, the water is drained, concentrated to 40%–50% solids through evaporation, and used as a nutrient-rich feed ingredient.

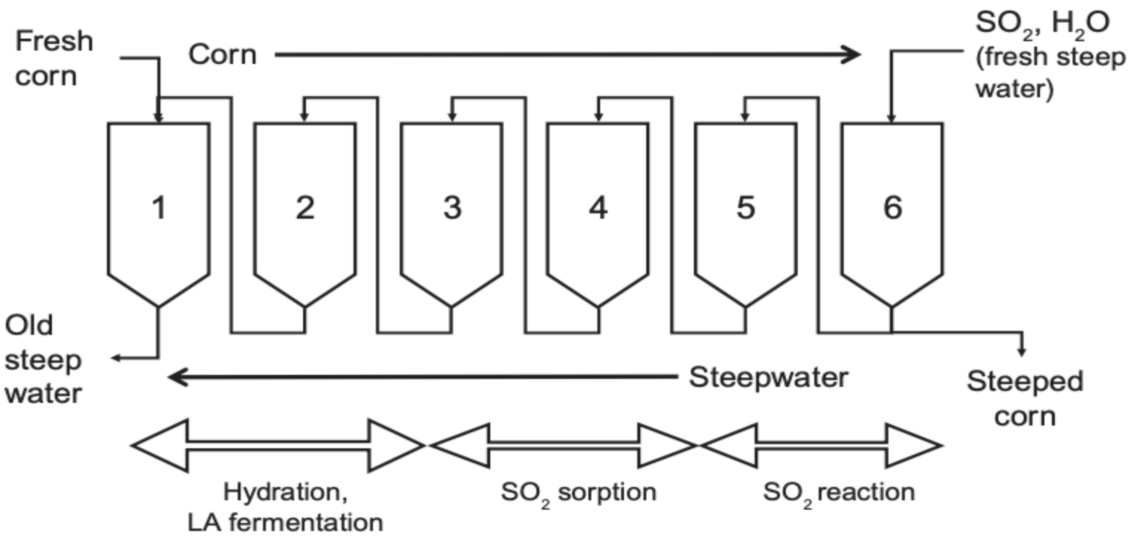


Figure Diagram showing phases of steeping during wet milling process

B. Coarse Grinding and Germ Separation

The steeped maize is coarsely ground using a disk mill to separate the germ, bran, and endosperm fractions. The mixture is then processed in a hydrocyclone system:

- Dense endosperm particles settle at the bottom.
- Lighter germ and bran fractions rise to the top.

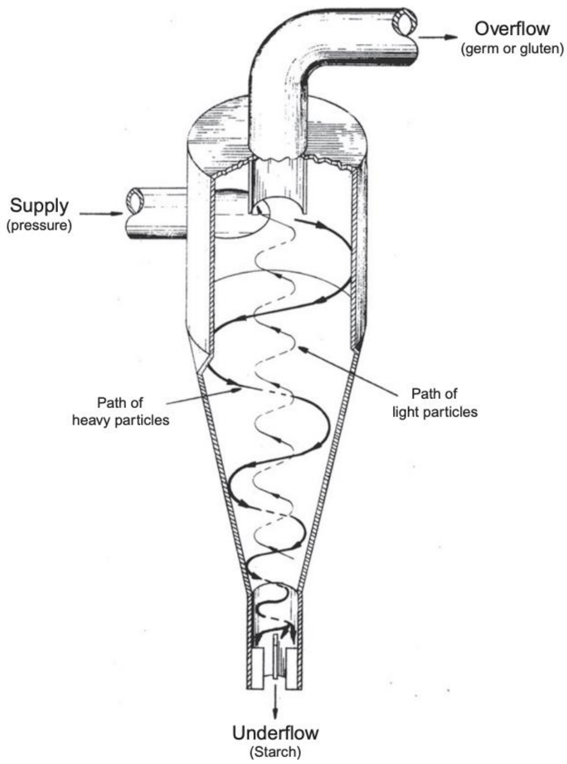


FIG. 18.6 Cut-away diagram of hydrocyclone separator. *(Courtesy of Watson, S.A., 1984. Corn and sorghum starches: production. In: Whistler, R.L., BeMiller. J.N., Paschall, E.F. (Eds.), Starch: Chemistry and Technology, second ed. Academic Press, Orlando, FL, pp. 418–468.)*

The germ is further separated from the bran and dried for oil extraction. Bran can be used alone or combined with fine bran and process water concentrate (gluten feed) for animal feed production.

C. Fine Grinding and Starch Recovery

The endosperm fraction is finely ground using a pin mill to release starch granules. The resulting slurry contains starch, gluten proteins, and fine fibers. It is processed through a series of sieves to remove fibers and hydrocyclones to separate the starch and gluten.

The starch is collected as a wet slurry and dried using flash dryers to produce native starch. If the starch is intended for modification or conversion (e.g., into dextrins, sugars, or ethanol), the drying step may be skipped. Gluten is dried to produce maize gluten meal, a high-protein ingredient used in animal feed.

Fractions and Yields

The conventional wet-milling process fractionates maize into five main products:

- **Prime Starch**: 60%–70% yield with >98% purity.
- **Germ**: 5%–10% yield, used for maize oil production.
- **Bran**: 10%–15% yield, used in animal feed.
- **Maize Gluten Meal**: 5%–10% yield, valued for its high protein content.
- **Process Water**: 2–3 times the weight of maize, with 4%–8% solids content.

High-Amylose and Waxy Maize

High-amylose and waxy (amylose-free) maize variants are used in specific niche markets, although their starch yields are slightly lower. These variants require minor adjustments in processing parameters but offer valuable starch properties tailored to specific applications, such as resistant starch for dietary fibers or highly viscous starch for thickening agents.

The wet-milling process for maize is a highly efficient method of fractionating the kernel into valuable components for food, feed, and industrial applications. Dent-type maize with high starch content and low hardness is ideal for maximizing yield and quality. While traditional wet-milling remains the global standard, adjustments for specific maize types and continued innovation ensure the process remains relevant for evolving market demands.

3.3. Ethanol production process

The diagram illustrates the combined **wet-milling** and **ethanol production process** from corn. It highlights the separation of corn components, enzymatic hydrolysis of starch, fermentation, and subsequent ethanol refinement.

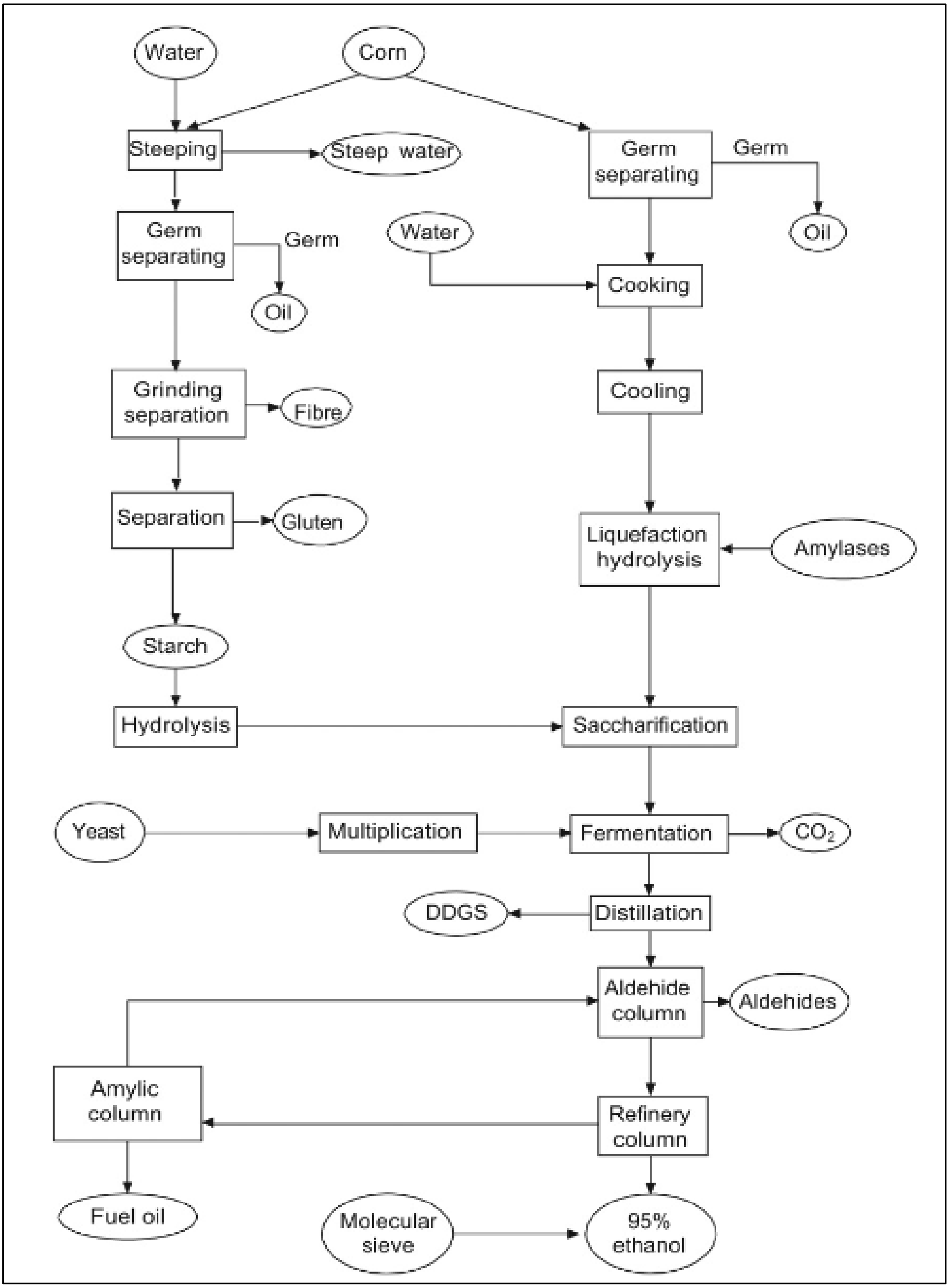


Figure 3. Ethyl Alcohol production from Corn.

- **Steeping:** Corn kernels are soaked in water, often with sulfur dioxide (SO_2) and lactic acid, to soften the kernels and begin breaking down the starch-protein matrix. Steep water is drained, concentrated, and often reused as a nutrient-rich byproduct.
- **Germ Separation:** After steeping, the kernels are coarsely ground, and the germ is separated. The germ, rich in oil, is extracted for corn oil production.
- **Grinding and Fiber Separation:** The remaining kernel (endosperm and bran) is finely ground to release starch granules. Fiber is separated from this mixture, often being used in animal feed production.
- **Gluten and Starch Separation:** In a series of steps, gluten proteins are separated from the starch. The gluten is dried and marketed as **maize gluten meal**, a high-protein animal feed. Purified starch is directed to either hydrolysis for ethanol production or sold as native starch.
- **Hydrolysis and Liquefaction:** For ethanol production, the purified starch undergoes **liquefaction and hydrolysis**. Enzymes such as **amylases** break down the starch into simpler sugars. During liquefaction, the starch is broken into shorter chains (dextrins), and saccharification converts these chains into glucose.
- **Fermentation:** Yeast is introduced to the glucose-rich slurry, where fermentation occurs. The yeast metabolizes the glucose, producing ethanol and carbon dioxide (CO_2) as byproducts. Yeast multiplication may occur to ensure sufficient activity for the fermentation process.
- **Distillation:** The ethanol-rich liquid from fermentation is distilled to separate ethanol from water and other components. Byproducts such as **dried distillers' grains with solubles (DDGS)**, used in animal feed, are recovered here.
- **Aldehyde and Refining Columns:** The distillation output passes through an aldehyde column to remove impurities such as aldehydes and other volatile compounds. A refining column is then used to purify ethanol further to approximately 95% concentration.
- **Molecular Sieving and Ethanol Purification:** The 95% ethanol is dehydrated using molecular sieves to remove the remaining water, producing nearly pure ethanol. Some ethanol may be further processed in an **amylic column** to separate heavier alcohols or blended as fuel oil.

Byproducts and Applications

The process generates multiple valuable products:

1. **Corn oil**: From germ processing.
2. **Maize gluten meal**: High-protein feed from gluten separation.
3. **DDGS**: A nutritious byproduct used in livestock feed.
4. **Ethanol**: Utilized as biofuel or in alcoholic beverages.

FE 401 FOOD TECHNOLOGY

LEGUMES/PULSES PROCESSING TECHNOLOGY

Prof. Dr. Mustafa BAYRAM
University of Gaziantep, Faculty of Engineering
Department of Food Engineering
27310-Gaziantep-TÜRKİYE

Rev4-Nov 10, 2017

LEGUMES X CEREALS

- Legumes absorp Nitrogen (fertilizer) from air, and relase to soil ➔ Lentils, soybean, peanut

- Cereals absorp nitrogen from soil ➔Wheat, corn, rice

====

Legumes X Pulses

====

Legumes: Botanic names only legumes plants

(Legumes → orginally vegetable)

Pulses (commercial term, contains some cereals and legumes:Bakliyat)

COMMON LEGUMES AND THEIR SCIENTIFIC NAMES

Common name	Scientific name
Peanut, ground-nut	Arachis hypogaea
Redgram, arhar	Cajanus cajan
Pigeon pea, yellow dhal, congo pea	Cajanus indicus
Chickpea, Bengal gram, garbanzo	Cicer arietinum
Horse gram	Dolichos biflorus
Lentil, masur dhal	Lens esculenta
	Lens culinaris
	Ervum lens
Broad bean, Windsor bean	Faba vulgaris
Soybean	Glycine hispida
	Glycine max
	Glycine soja

Lupin	**Lupinus SPP**
Velvet bean	Mucuna pruriens
Mung bean, green gram,	Phaseolus aureus golden gram
	Phaseolus radiatus
	Vigna radiate
Lima bean	Phaseolus lunatus
Black gram, urd, mungo bean	Phaseolus mungo
Kidney bean, navy bean, pinto bean,	
haricot bean, snap bean	Phaseolus vulgaris
Pea	Pisum sativum
Winged bean	Tetragonolobus purpureus

Adzuki bean, azuki bean, Adanka bean, danka bean (Vigna angularis, syn.: *Phaseolus angularis*)

Broad bean, faba bean, fava bean, bell bean, field bean, tic bean (*Vicia faba*)
(large-seeded broadbeans, windsorbeans- *V. faba* var. major)
(horsebeans- *V. faba*) var. major)
(small, round-oval seeded tickbean, pigeon bean- *V. faba* var. minor)
Vetch, common vetch (*Vicia sativa*)

Common bean, common field bean, kidney bean, navy, habichuela, snap bean (*Phaseolus vulgaris*)

Chick pea, Bengal gram, calvance pea, chestnut bean, chich, chich-pea, dwarf pea, garavance, garbanza, garbanzo bean, garbanzos, gram, gram pea, homes, hamaz, nohub, lablabi, shimbra, yellow gram (*Cicer arietinum*)

Cowpea, asparagus bean, black eyed pea, black eyed bean, crowder pea, field pea, southern pea, frijole, lobhia, kibal, nieve, paayap (*Vigna unguiculata*, syn.: *Vigna sinensis*)

Guar bean, cluster bean, gawaar, gwaar ki phalli (*Cyamopsis tetragonoloba*)

Hyacinth bean, bonavist, bataw, lablab (*Dolichos lablab*)

Lentil, black lentil, brown lentil, green lentil, green mungbean, large-seeded lentil, red mungbean, small-seeded lentil, wild lentil, yellow lentil, adas, mercimek, messer, masser, heramame (*Lens culinaris*)

Lima bean, butter bean, patani (*Phaseolus lunatus*)

Top World Producers of Some Grain Legumes, 2008 (FAOSTAT, 2010):

Beans, dry- Brazil
Broad beans, horse beans, dry- China
Chick peas- India
Cowpeas, dry- Nigeria
Lentils- Canada
Lupins- Chile
Peanuts (groundnut), with shell- China
Peas, dry- Canada
Pigeon peas- India
Soybeans- USA
Vetches- Ethiopia

KERNEL

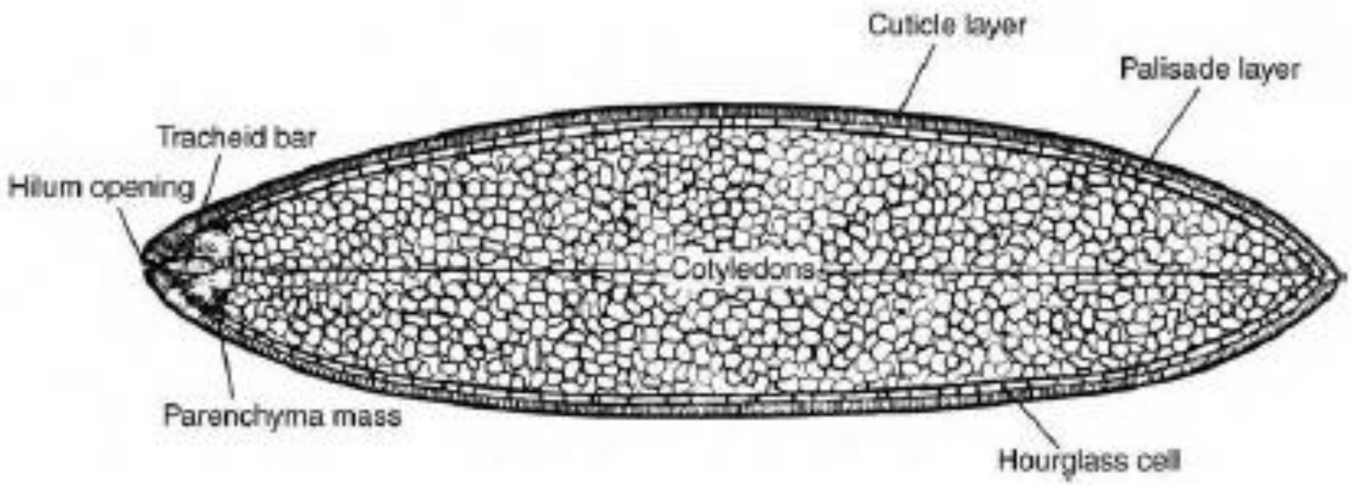


FIGURE 18.1 Schematic diagram of the structure of a cross section through a lentil seed. (From Ref. 2.)

Soybean and dry pea have only 5–8% hulls that are easily removed; other pulses contain 10–18% hulls that are removed by abrasive dehullers, or after soaking or boiling.

Ash content analysis = Shows BRAN content
(bran contein high amount of mineral (inorganic material)

Unsoluble ASH in 10% HCl sol'n: Shows silisium (sand, soil, stone) dirtiness of product (slisium is not soluble in HCl

Bulk density↑(hectoliter-weight)=Shows kernel size ↑ (bran content↓, yield↓)

Energy and Chemical Constituents in Food Legumes

Common Name	Energy kJ/100 g	Protein*	Lipid	Starch	Sugars	Ash	Total Dietary Fiber
		% Dry Weight Basis					
Proteinaceous Oilseeds							
Peanut	2255	28	53	1	5	2	8
Soybean	1695	39	20	2	8	5	22
Lupin	1565	38	10	2	10	4	33
Starchy Pulses							
Common bean	1468	24	2	42	5	4	21
Dry pea	1418	20	1	52	5	3	17
Chickpea	1520	19	6	50	7	3	18
Fababean	1430	28	2	45	4	3	17
Lentil	1442	24	1	52	6	2	13
Pigeon pea	1443	21	2	46	6	4	19
Cowpea	1442	24	1	47	7	4	15
Mung bean	1445	25	1	47	4	4	23
Lima bean	1420	21	1	43	5	5	23

* N × 5.7.

Intestional gas problem (Sugar)

Food legumes in general contain significant concentrations of free sugars (4–12%) (Table 18.2), which are composed of about 40% disaccharides (sucrose mainly) and 60% α-galactosides (raffinose, stachyose, and verbascose) (13). The latter group represents a problem for consumers since the human digestive system lacks the enzyme α-galactosidase. Thus this raffinose family of oligosaccharides passes into the large intestine where sugars are fermented anaerobically to produce gas.

Hardness (Hard cooking)

The hulls of pulses contain about 50% cellulose, 20% hemicellulose, 20% pectin-like and water-soluble carbohydrates, and 2–12% lignin, condensed tannins, and procyanidin. The hydroxyl groups of the latter compounds form cross-links with proteins to cause seed hardening during storage and decreased protein digestibility during cooking (5).

Safe storage condition

-m.c. <13%
-R.H.: <70% or 75%
-T<25 C
-Dry
-Prevent inside heat generation due to biological activity (kızışma), m.o., insect etc.

It is generally same for cereals

Processing

Legumes go through several primary processes-

1) Bean-Chickpea etc.

1- Pre-cleaning (sieving, destoner, foreign seed removing, sorting, dust removing)

2- Calibration

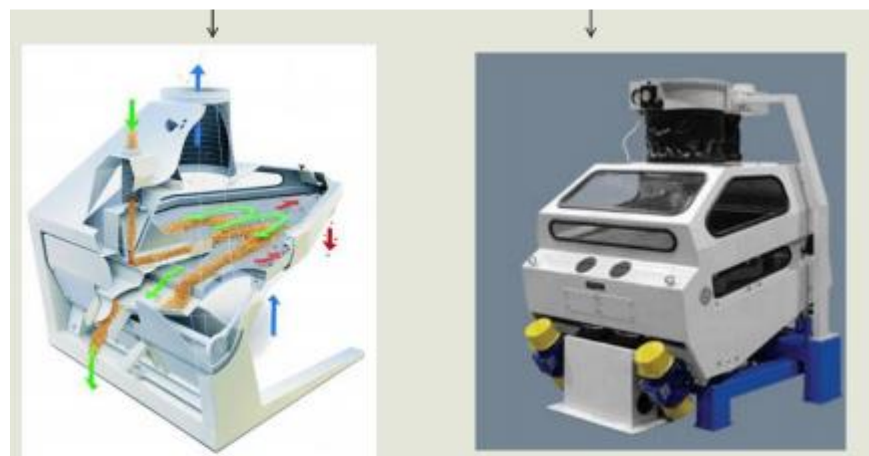
3- Packaging

EQUIPMENT

Cleaning screen(Posta eleği)

Trior-Intented cylinder
(to separate broken kernel and foreing seed)

Calibration screen



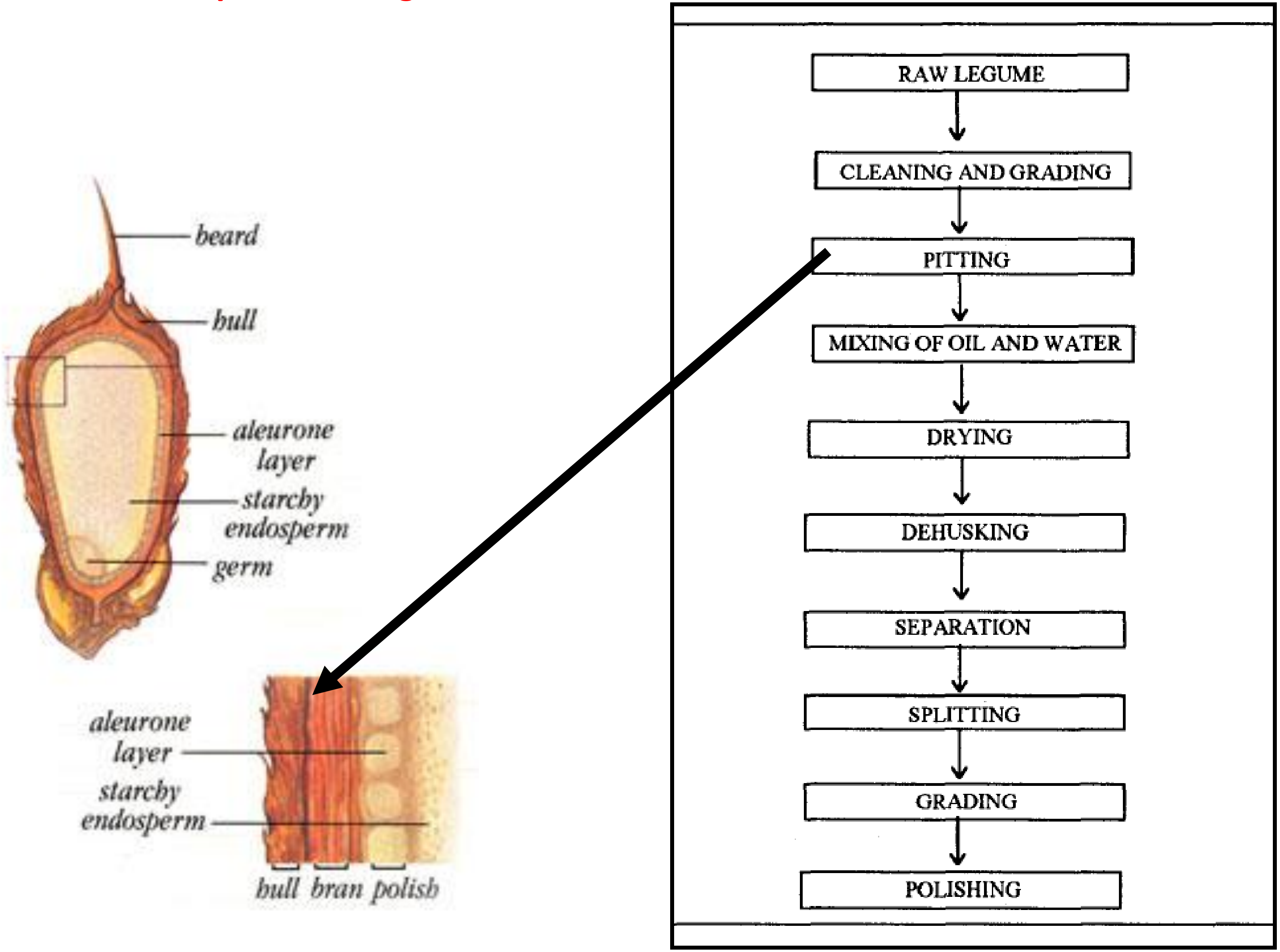
Destoner

2) Dehulled/Splitted (lentils, soybean, pea etc.)

- hulling (husking),
- puffing,
- grinding,
- splitting, etc.-before they are used in different food preparations.

Conventional pulse milling

Figure 4 Conventional method of pulse milling.



Wet pulse milling

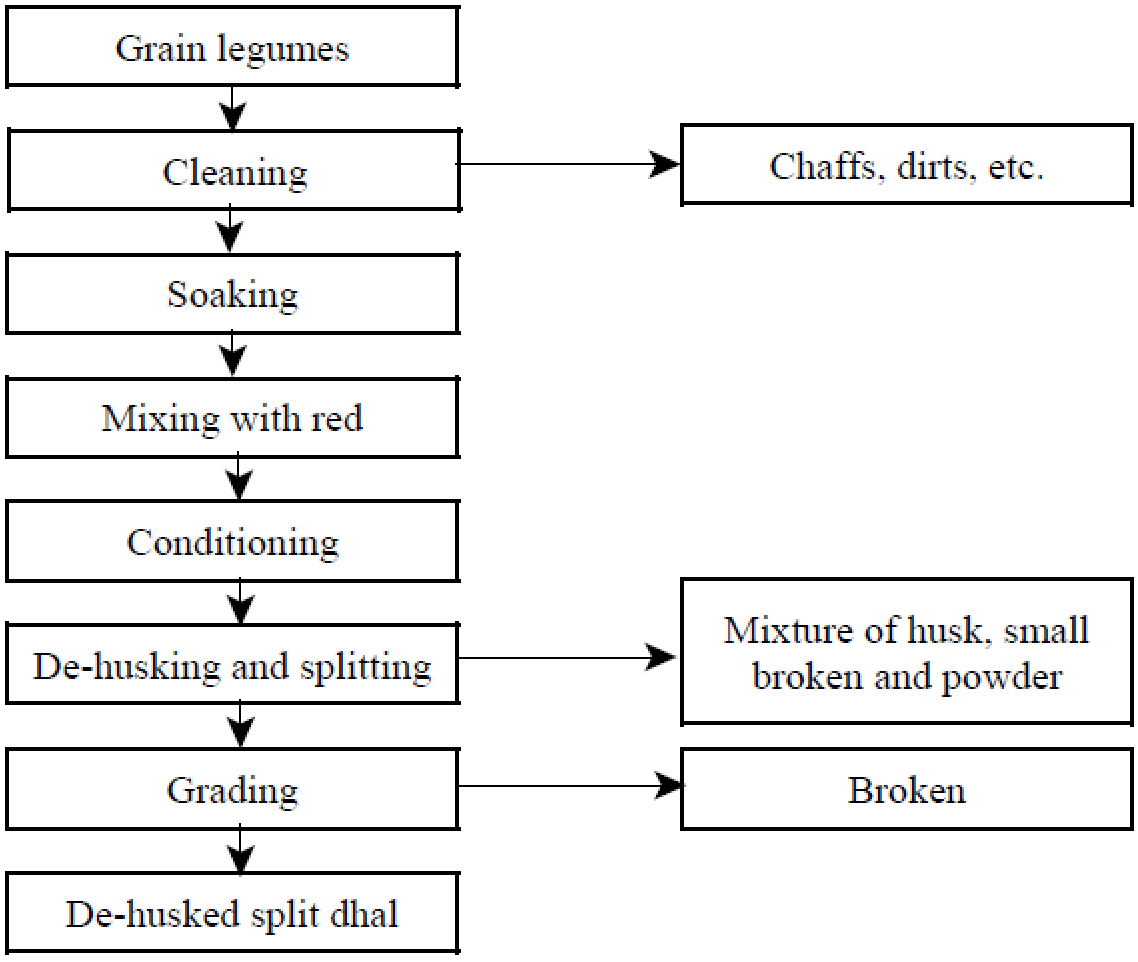


Figure 1. Flow Chart of Wet Milling Grain Legumes

Dry pulse milling

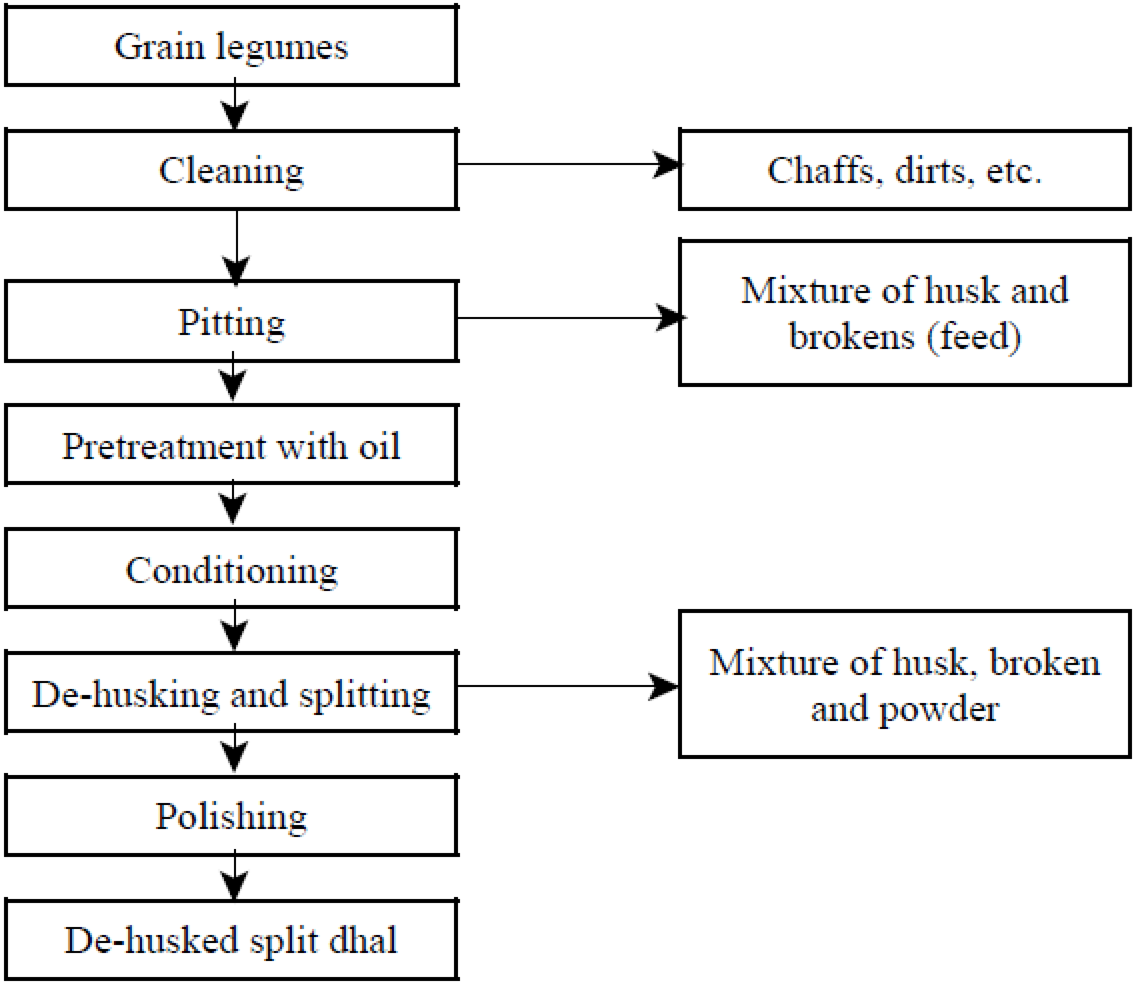


Figure 2. Flow Chart of Dry Milling Process

Explanation of process steps for pulse milling

Cleaning and grading	Raw pulses are cleaned by removing dust, dirt, foreign material, off-sized, immature and infested grains and graded. The dockage varies 2-5 percent. It depends on crop, season, etc.
Pitting	Whole pulse grains after cleaning are passed through abrasive roller machine for scratching of seed coat to facilitate the entry of oil/water in the grain during pre-milling treatment. Two to 5 percent grain get de-husked during pitting

Oil and water treatment	Edible oil is applied to difficult to mill pulses for loosening of husk. The quantity of oil used varies from mill to mill and State to State and depends mainly on the type and size of the grains, variety, moisture content, etc. It is estimated that about seven million mt of pulses require oil treatment. The quantity of oil used is estimated to be 21,000 mt (300 gm/100 kg) worth Rs.630 million or US$14 million. Though a major part of this oil forms an edible portion of the product the actual oil consumption is not affected. Hence, saving of such oil by process modification/development is the only answer.
	Water treatment, which varies with crop and place, is given to grains to achieve expansion for loosening of husk through drying when cotyledons shrink in size. More the water applied, longer would be the process/drying time and more energy requirement for drying. Some millers apply water and oil simultaneously. This reduces the total processing time.

Tempering	Treated grains are heaped and covered and left for 12-18 hours. It helps in penetration of oil/water into the cotyledons after oil/water mixing and equilibration of grain temperature after drying in the sun. At some places, wooden/cement tanks are used for tempering the treated grains.
Drying	Normally sun-drying is followed. Drying period varies from one day to five days depending upon weather conditions. Some dhal mills are equipped with dryers for continuous operation of the mill especially in the rainy season and/or unfavorable weather conditions.
De-husking and splitting	De-husking of pulse grains is a preparatory operation for splitting. In case of pulses (green gram, black gram, cowpea) having thin seed coat, there is a tendency to split them before de-husking. This needs many passes for complete de-husking and adds to breakage. De-husking is preferably achieved by subjecting the grains to abrasive force and splitting by attrition and/or impact. Generally 3-9 passes are required for milling of different pulses and this depends on the type of pulse crop, pre-milling treatment, grain size, variety, etc.

	[illegible]
Husk separation and grading	Husk is separated with aspirator and sold as livestock feed. Some find brokens go along with the husk and if separated, can yield extra quantity of dhal for human consumption. Grading adds to the quality of the product.
Polishing	Splits (cotyledons)/dhal and some of the pulse grains, namely black gram, green gram, lentil, and peas are polished to add luster and shine to the product. Dhal is polished in different ways such as nylon polish, oil/water polish, color polish, etc. Some consumers prefer unpolished dhal.

Processing for germination pulses (Pulse sprouts)

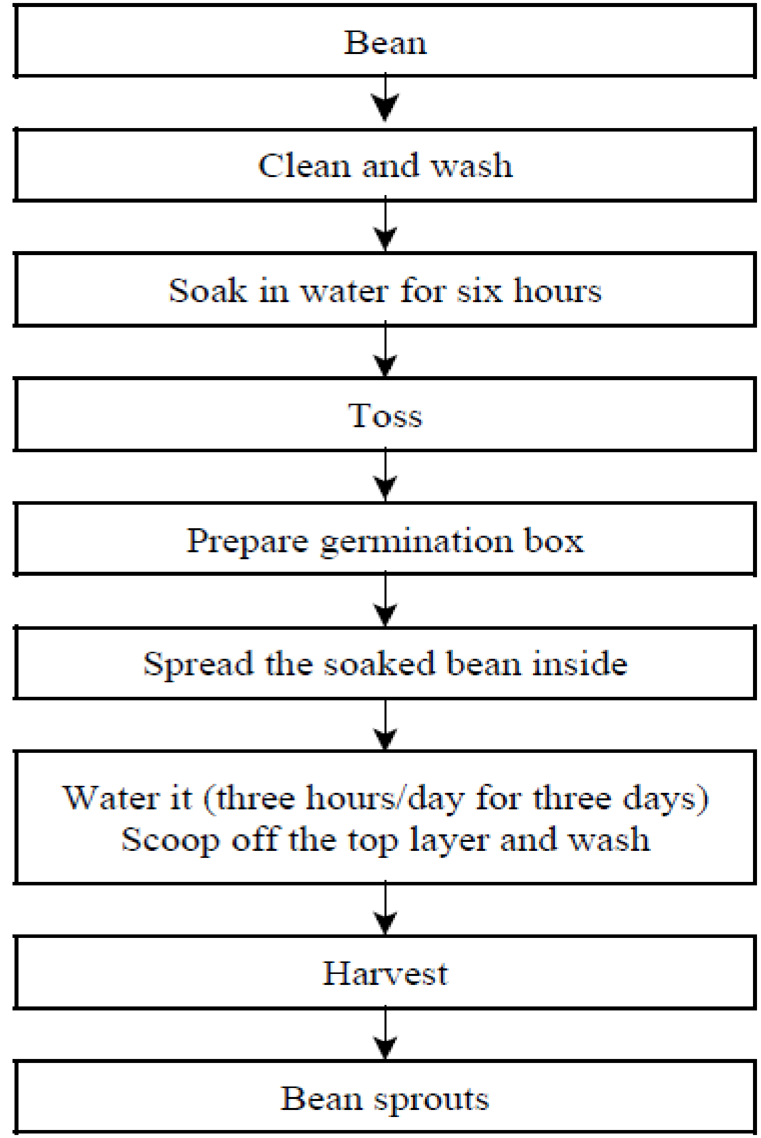
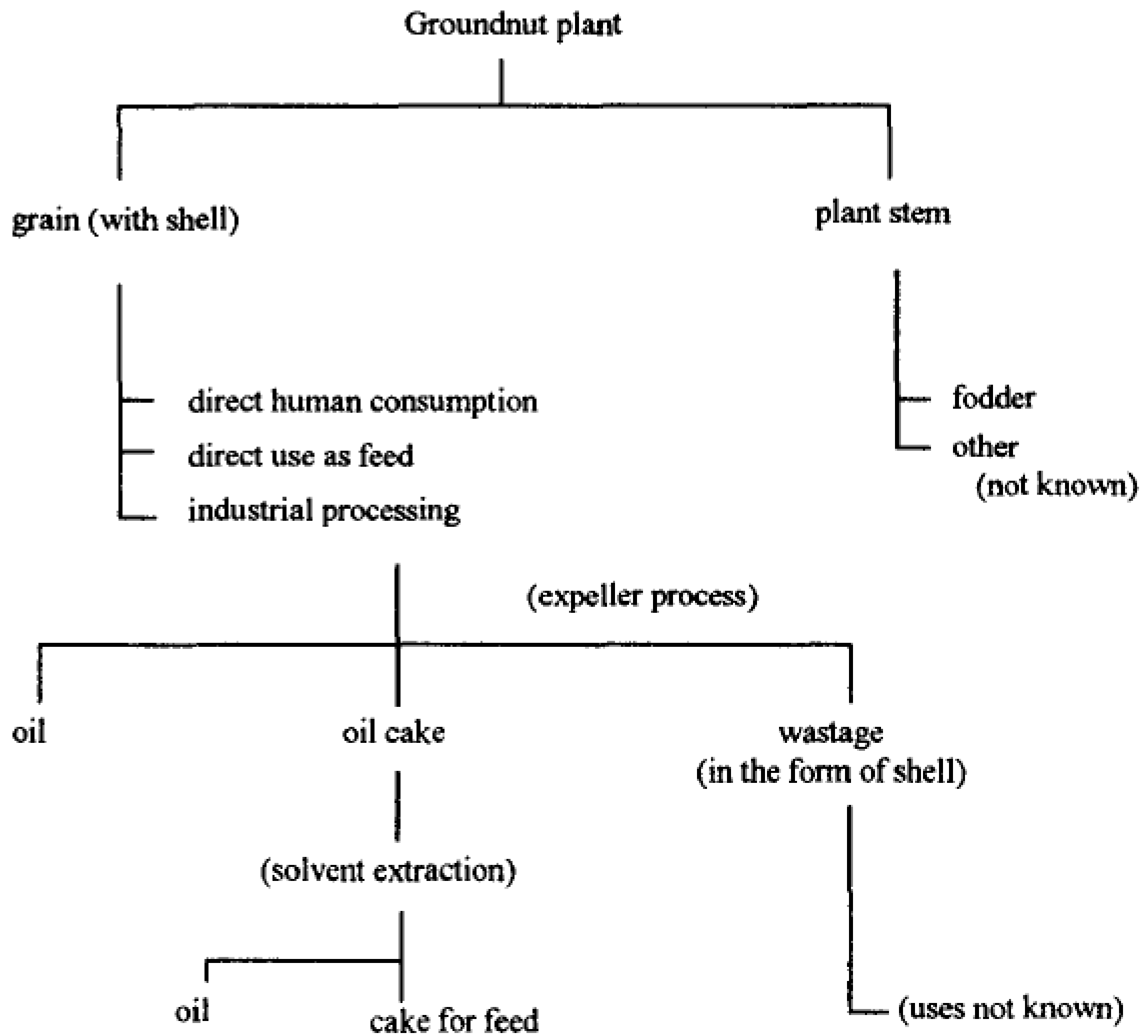


Figure 2. Processing of Bean Sprouts

Processing of Peanut (Groundnut)

Figure 5 Groundnut product system.



Processing of Peanut butter

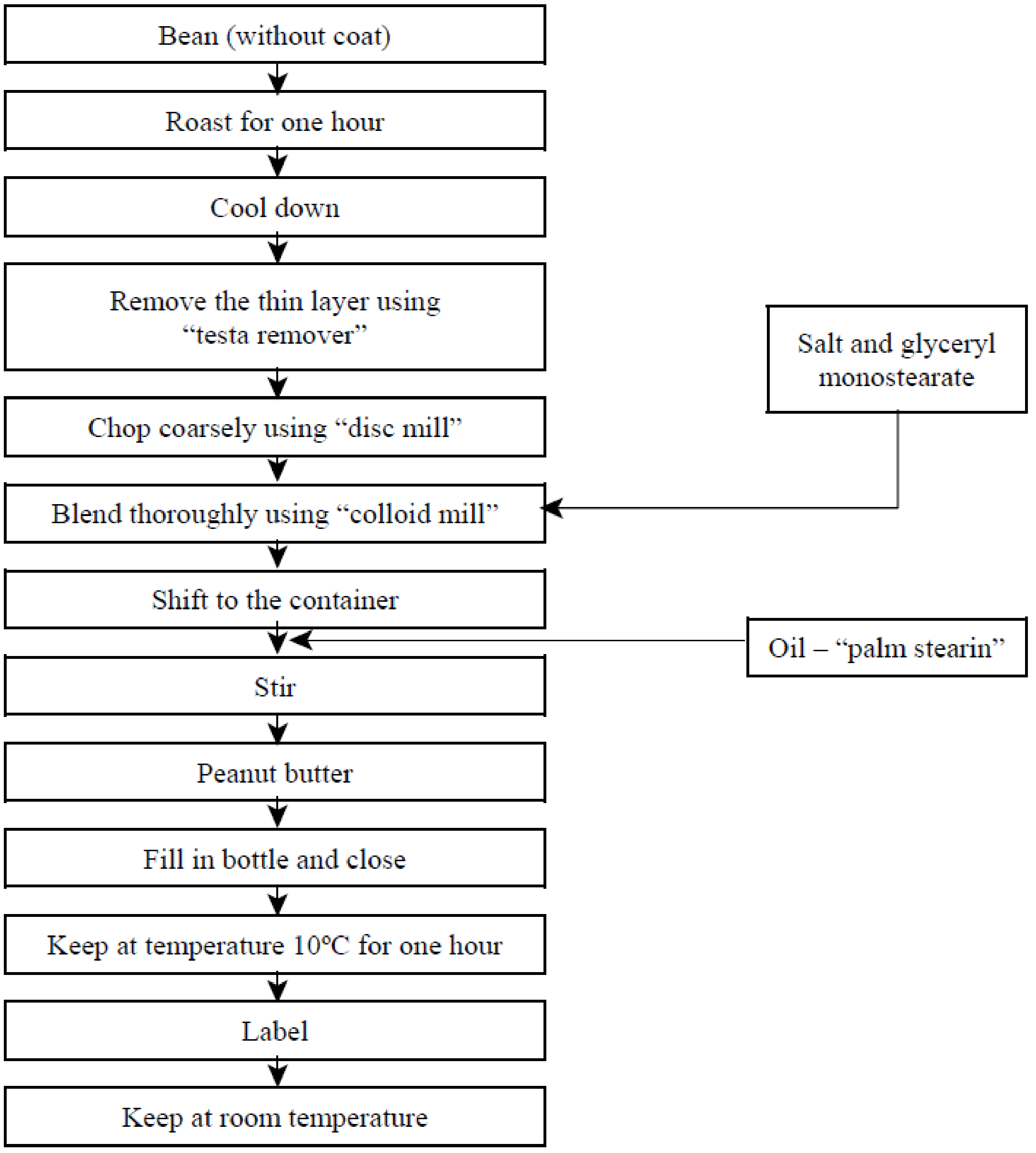


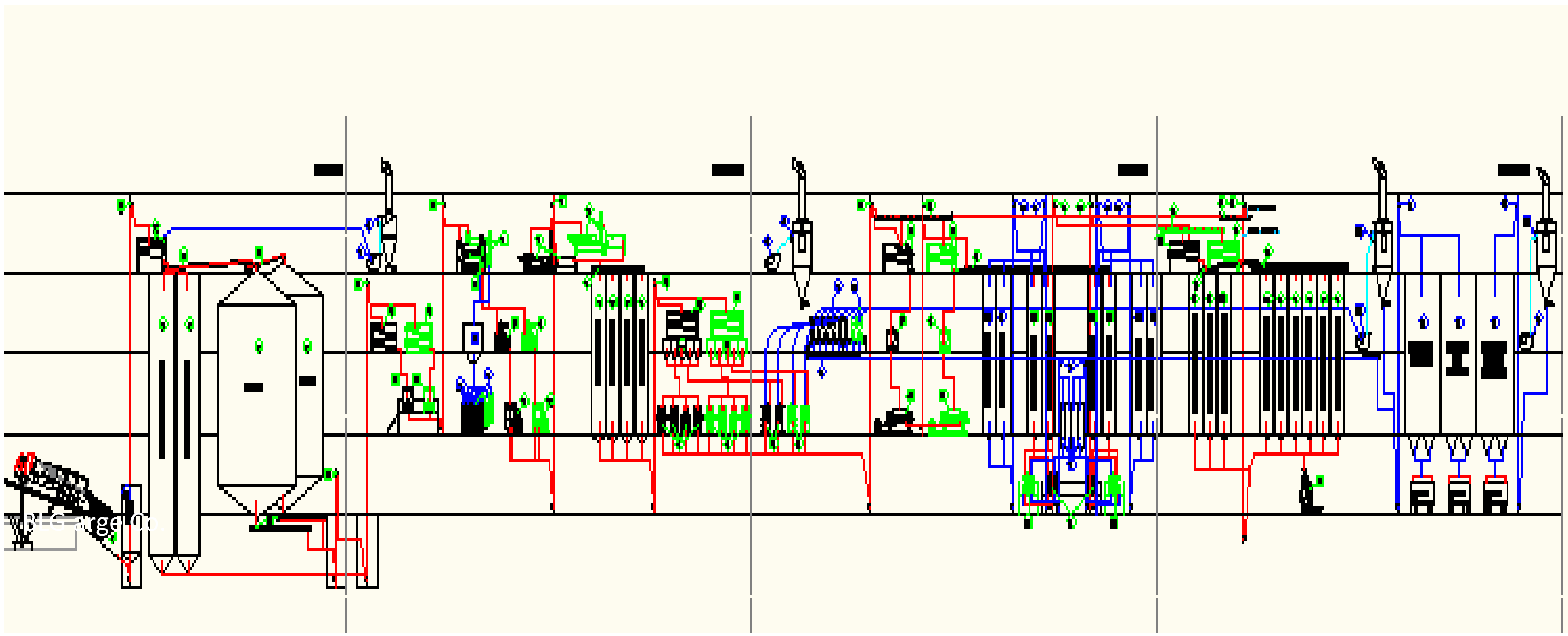
Figure 5. Processing of Peanut Butter

Processing of red lentils

RED LENTIL

Cleaning (sieving+destoning+aspiration etc.)

→**water addition (tempering)**→**dehulling or/and splitting**→others



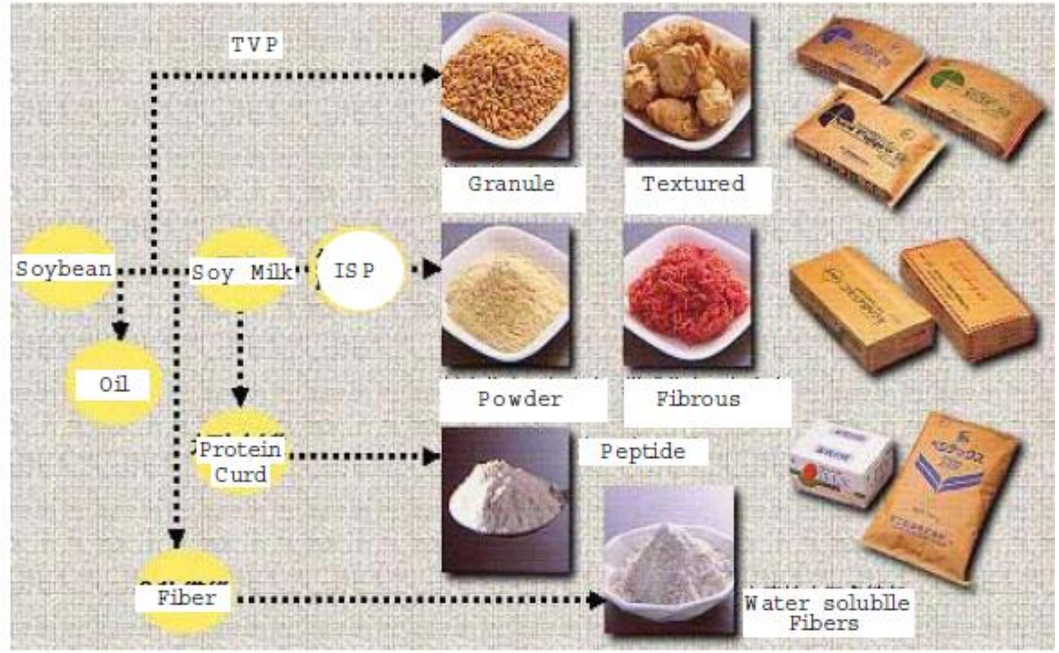
Processing of soybean

Table 28. Soybean Food Potential and Options – Technology and the Products

Soybean Form Used	Technology	Products
Whole soybean (direct use)	Separation, soaking, blanching, boiling, drying, size reduction, fermentation, extrusion, packaging, storage and marketing.	Full-fat soy flour, milk, paneer (tofu) curd, ice-cream, *tempeh*, sauce, sprouted and roasted snack, extruded snack foods, soy-fortified bakery and fermented foods.
Partially defatted soybean (oil and cake)	Mechanical expression, physical refining, enzyme, cooking, size reduction, packaging, storage and marketing.	Oil, margarine, medium fat soy flour, bakery foods, aqua and animal feeds.
Fully defatted soybean (oil and meal)	Solvent extraction, refining, hydrogenation, size reduction, separation and concentration, packaging, storage and marketing.	Oil, *vanaspati*, soy meal, defatted soy flour, lecithin, soy protein concentrate, isolates and hydrolysates, specialty and health foods.
Byproducts of soybean (hull, *okara* and whey)	Dehydration, size reduction, fermentation, separation, packaging, storage and marketing.	Dietary fiber, single cell proteins, citric acid, enzymes, alcohol.

Figure 4 Soybean product system.

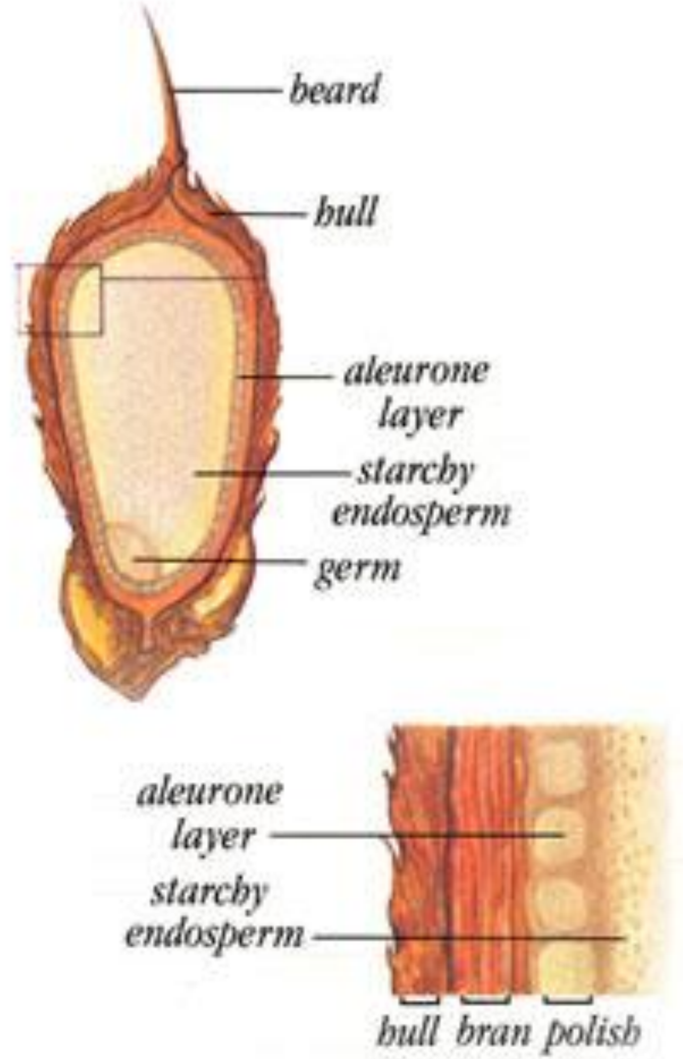
- grain
  - direct human consumption
  - direct use as feed
  - industrial processing
    - Products of soybean
      - food
        - fermented food
          - *shoyu* (soy sauce)
          - *miso* (soy paste
          - *sufu* (soy cheese)
          - *tempeh* (soy cake)
          - *natto* (whole soybean)
        - non-fermented food
          - soymilk
          - *tofu* (soymilk curd)
          - *kori-tofu* (dried tofu)
          - *yuba* (coagulant film of soymilk)
          - *kinako* (roasted soy powder)
          - *moyashi* (soybean sprout)
      - oil
        - cooking oil
        - industrial uses
          - water based alkyd coatings (plasticizer)
          - oleochemicals
          - fuel mixture
          - printing inks
          - defoaming agent
      - meal
        - animal feed
- stalk
  - fodder




RICE
al-faizan

Kernel

Varieties



Paddy

BASIC

Bran

Paddy **=Çeltik**

Cargo/Brown =Kargo

Husk/Hull=Kavuz

TYPES



-Depend on size of kernel

-Depend on starch/amlylose and amylopectin

Starch → Amylose + Amylopectin

Kernel size↓ → Amylopectin↑ → Stickness↑

TYPES

1-Long rice
(**<u>low amylopectin-</u>**
Not sticky property)
Basmati (!)
Jasmin
(good pilaf)

2-Medium size rice
Calrose
Baldo
Osmancık
Good pilaf

3-Short rice
(**high level amylopectin**)
-Sticky
-Asian food
Sticky pilaf

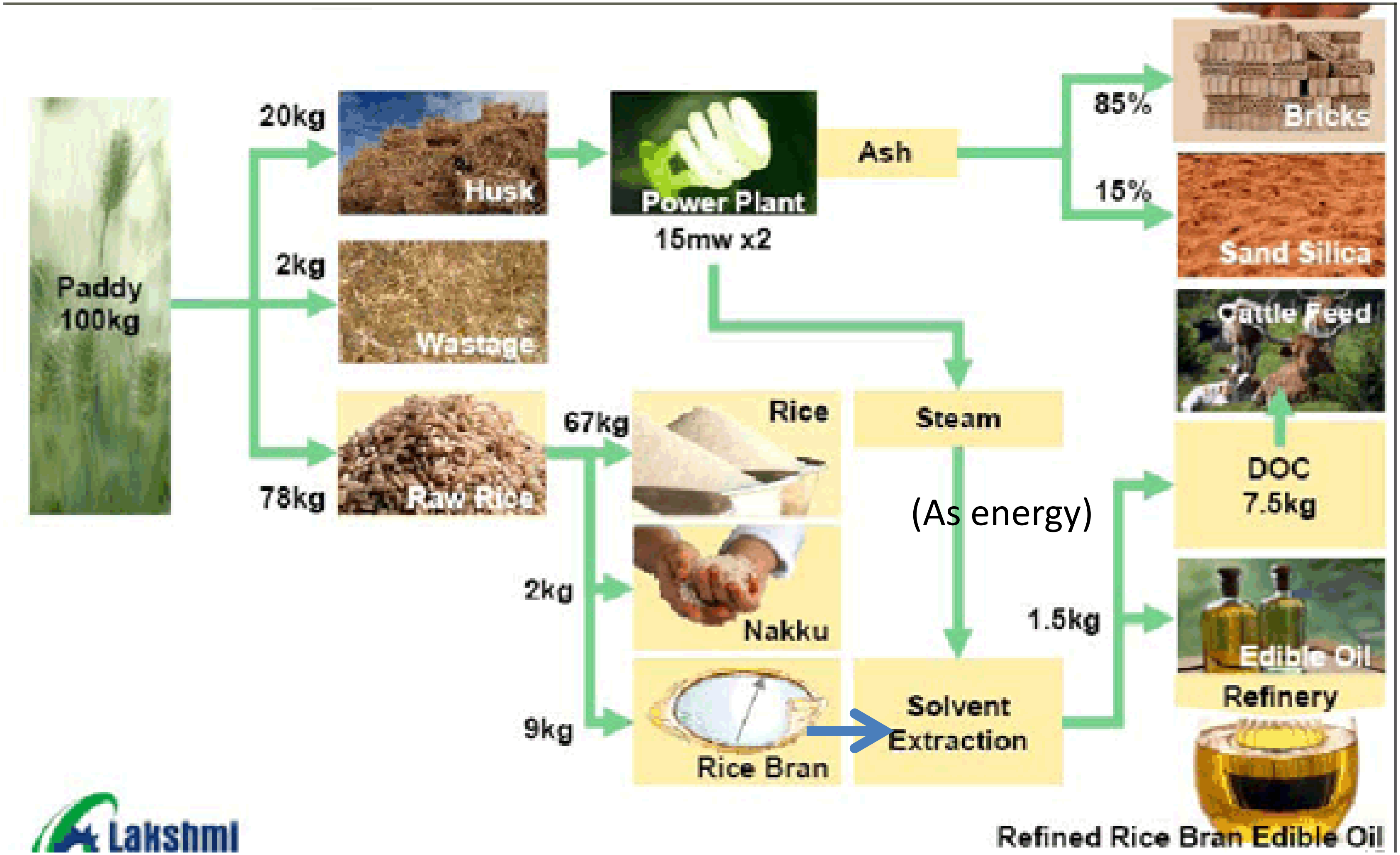
Detail:

Rice contains two types of starch: amylose and amylopectin. The amount of each starch, which is different for every type of rice, determines the texture of the cooked rice and whether it will be fluffy, creamy or sticky. As rice cooks, both the heat and liquid penetrate the grain and the starch molecules inside the grain break down. As the liquid is absorbed, each starch carries out a different task.

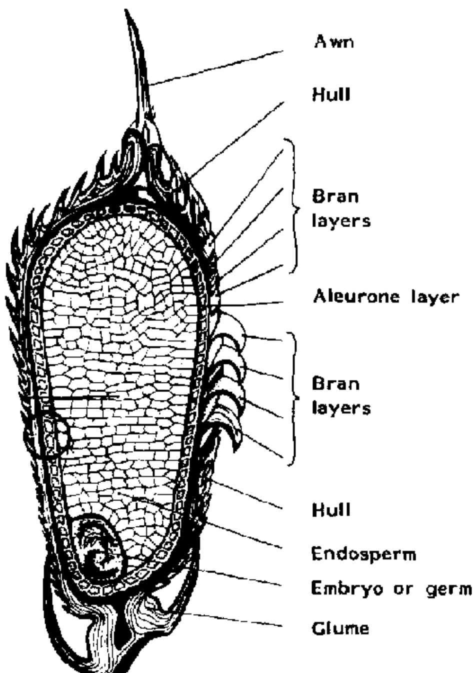
Amylose is a long, straight starch molecule that does not gelatinize during cooking. Grains with high amounts of amylose will be fully and separated once cooked. Long grain rice typically has high amounts of amylose (about 22%) and the least amount of amylopectin (ex., long grain varieties, Basmati and Jasmine).

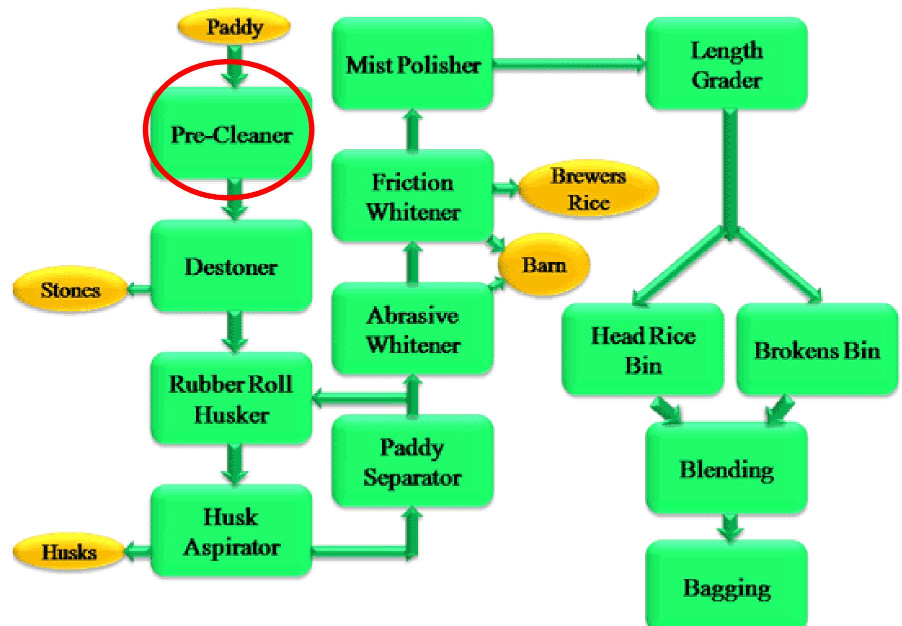
Amylopectin is a highly branched starch molecule that is responsible for making rice gelatinous and sticky. Rice with a high amount of amylopectin will be very sticky once cooked. Short grain rice typically contains the lowest levels of amylose and the highest of amylopectin (ex., short grain, Asian-style types of rice). The characteristics of some medium grain rice tend to fall somewhere in between. They typically contain about 15-17% amylose and a good amount of amylopectin which results in a creamy consistency (Italian, Arborio, and paella-style types of rice).

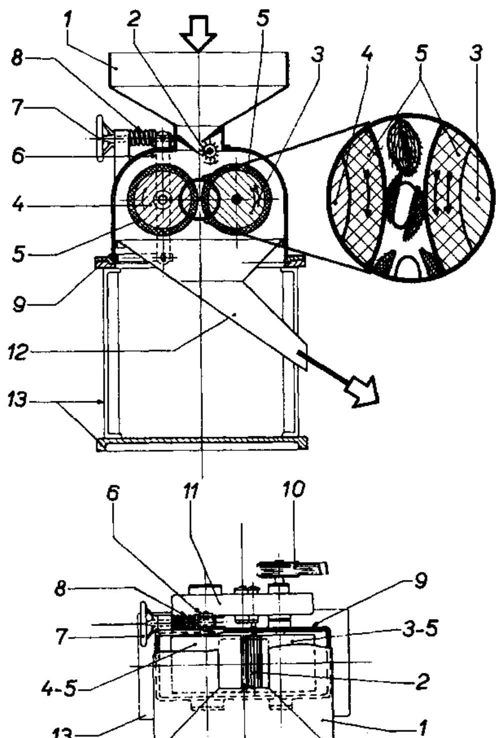
Sticky rice (a.k.a., glutinous, waxy or sweet rice) is very sticky when cooked. It contains the highest amount of amylopectin and no amylose. It's often used to make sweet dishes in Asia.


Paddy
100kg
20kg
Husk
2kg
Wastage
78kg
Raw Rice
Power Plant
15mw x2
Ash
85%
Bricks
15%
Sand Silica
Cattle Feed
67kg
Rice
2kg
Nakku
9kg
Rice Bran
Steam
(As energy)
Solvent
Extraction
DOC
7.5kg
1.5kg
Edible Oil
Refinery
Refined Rice Bran Edible Oil
Lakshmi

Rice Processing Details



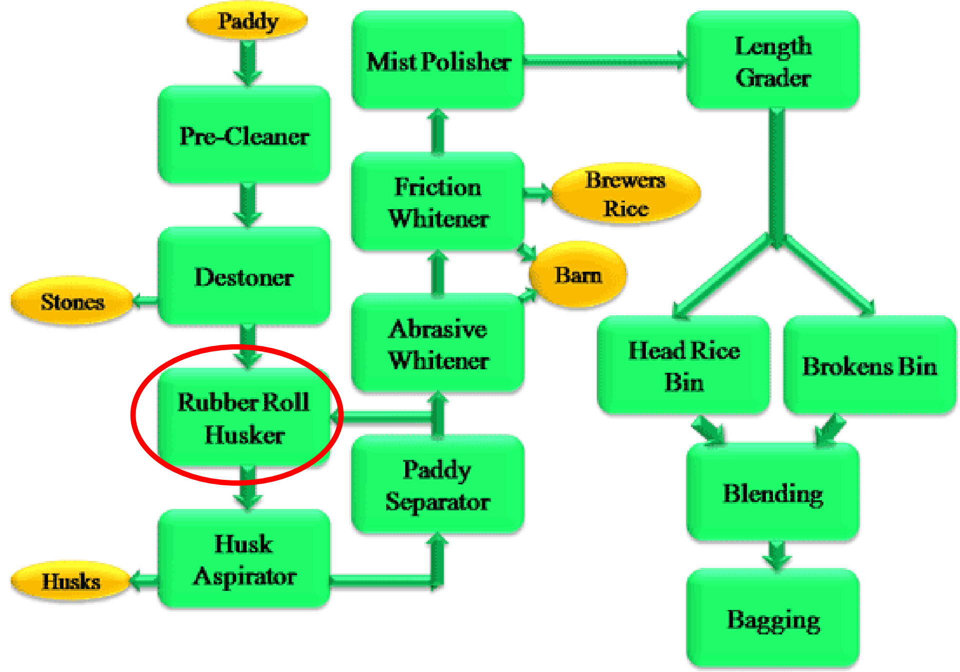




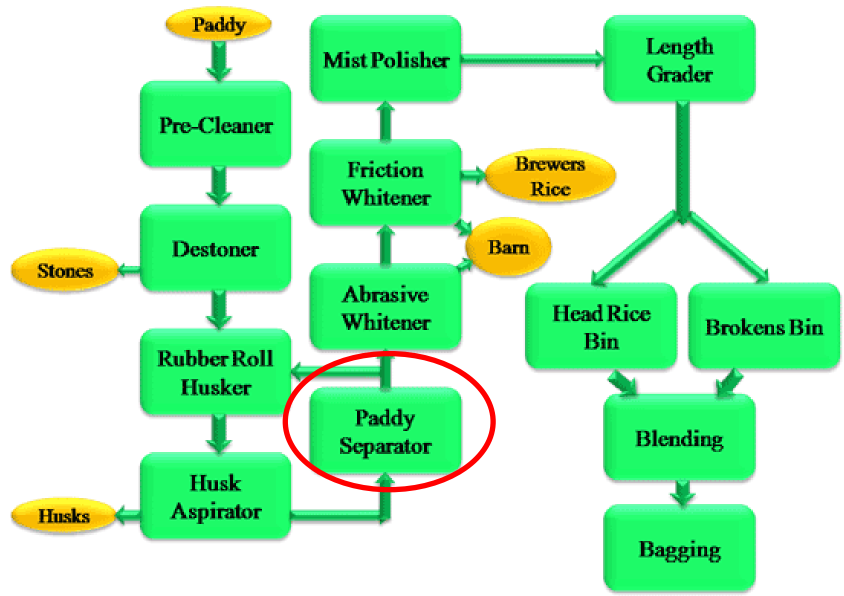
Used for paddy hulling

Key

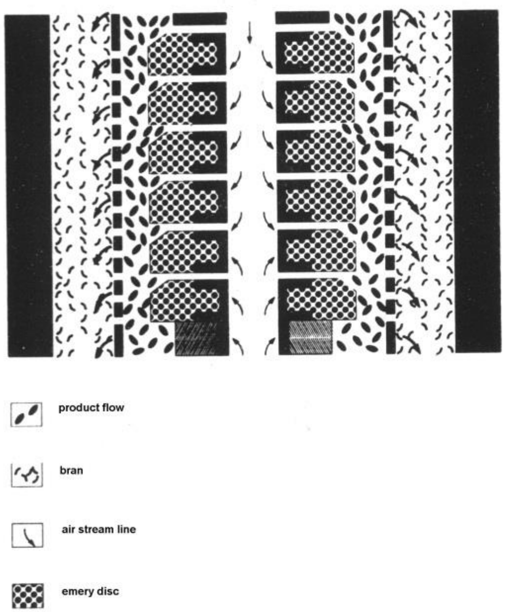
1. Feed hopper; 2. Feed roller; 3. Fast roll; 4. Slow roll; 5. Rubber surface; 6. Roll adjusting arm; 7. Roll adjusting hand-wheel; 8. Compression spring; 9. Housing; 10. Drive pulley; 11. Drive unit housing; 12. Outlet spout; 13. Base and frame.




Step 6: Paddy Separating
Cleaned White Rice
Paddy Saperator
Rice Without Paddy
Rejection

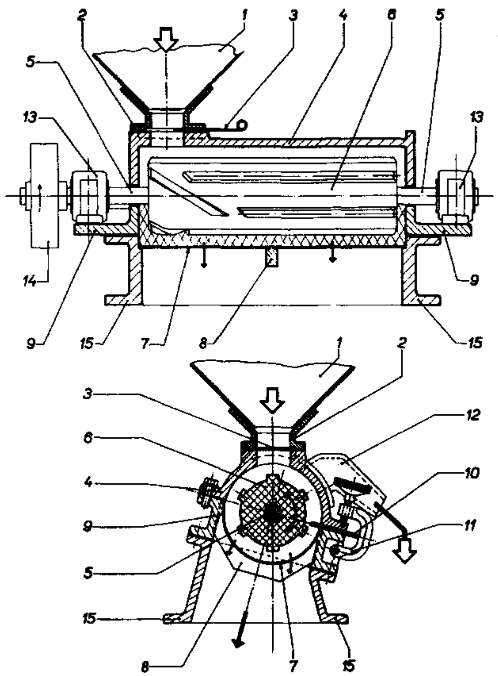

Paddy
Pre-Cleaner
Destoner
Stones
Rubber Roll Husker
Husk Aspirator
Husks
Paddy Separator
Abrasive Whitener
Friction Whitener
Brewers Rice
Barn
Mist Polisher
Length Grader
Head Rice Bin
Brokens Bin
Blending
Bagging

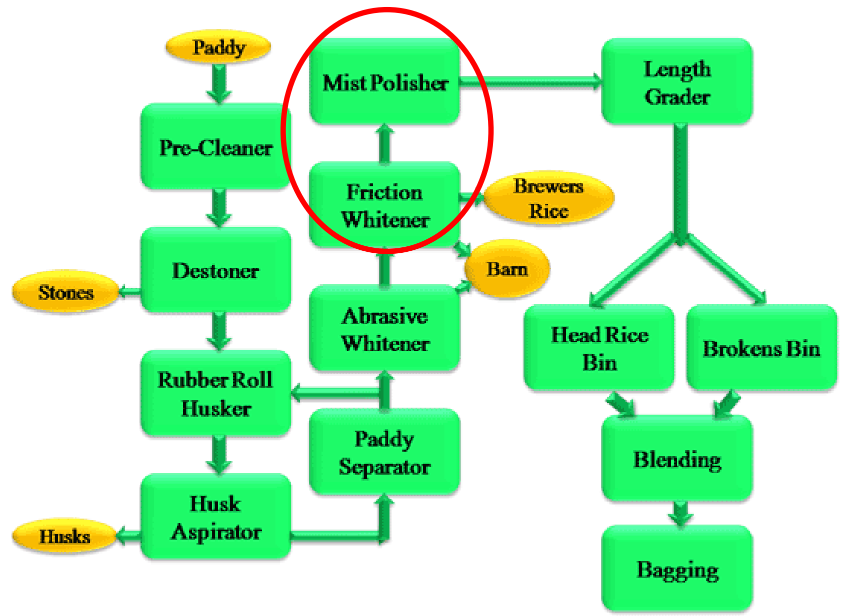

STEP 3: WHITENING
BROWN RICE
WHITENER
WHITE RICE
REJECTION


product flow
bran
air stream line
emery disc


Paddy
Pre-Cleaner
Destoner
Stones
Rubber Roll Husker
Husk Aspirator
Husks
Paddy Separator
Abrasive Whitener
Friction Whitener
Barn
Brewers Rice
Mist Polisher
Length Grader
Head Rice Bin
Brokens Bin
Blending
Bagging

Step 8: Polishing

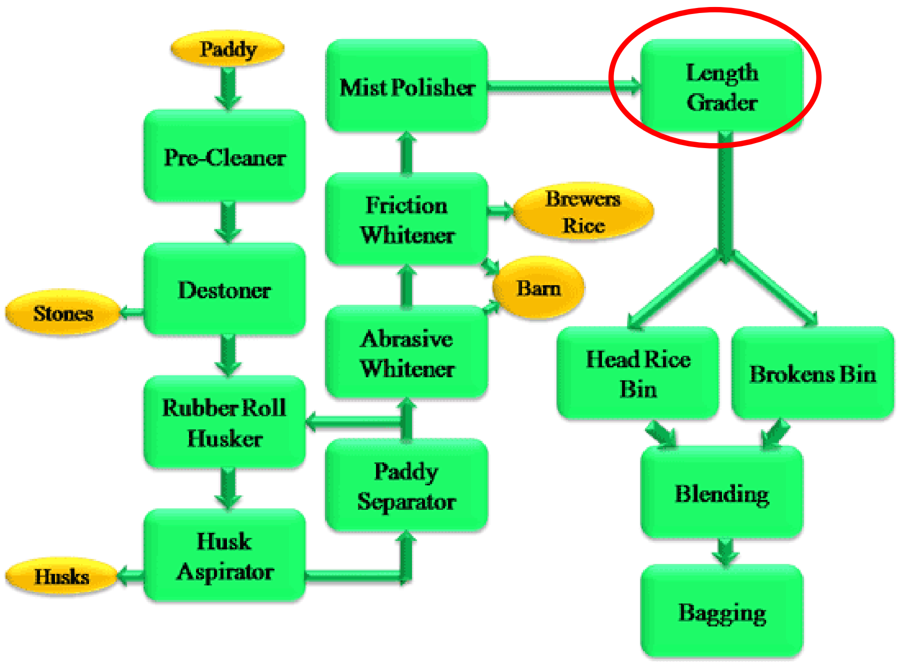


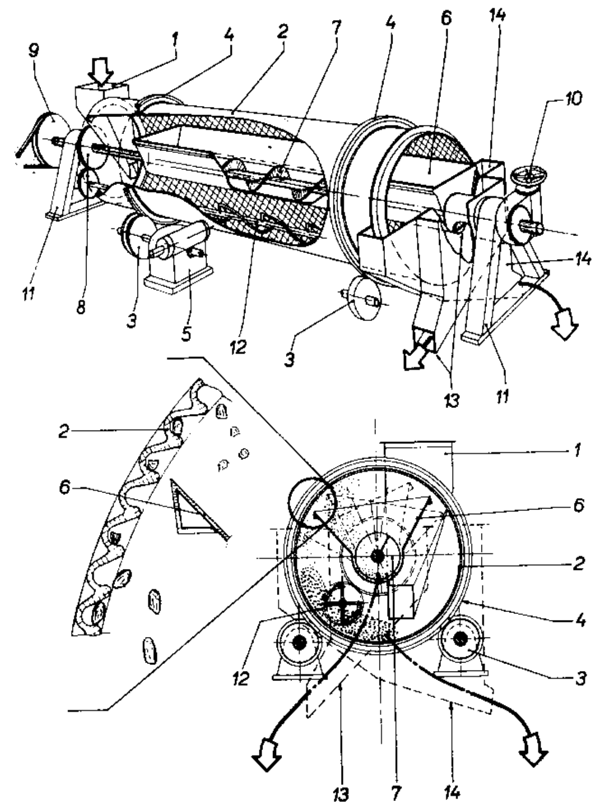


Used for paddy hulling and whitening

Key

1. Feed hopper; 2. Hopper base; 3. Feed regulating gate; 4. Cover; 5. Shaft; 6. Steel roll/shaft; 7. Screen; 8. Screen holder; 9. Frame; 10. Hulling blade; 11. Cover clamp; 12. Outlet spout; 13. Bearings; 14. Drive pulley; 15. Frame.



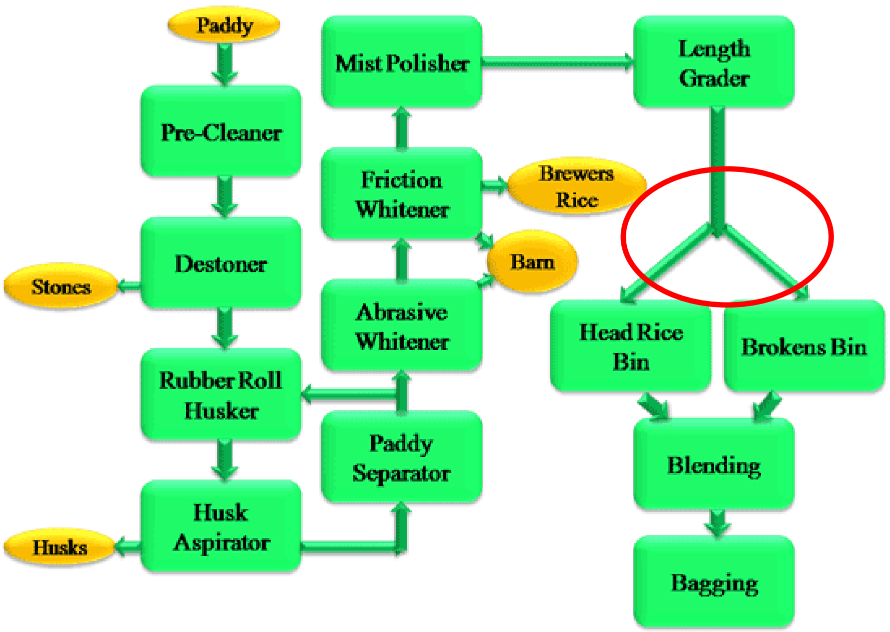


Used for paddy grading and cleaning, hulled rice grading, and rice grading

Key

1. Feed hopper; 2. Indented cylinder; 3. Cylinder supporting roll; 4. Outer cylinder ring; 5. Speed reducing gearbox; 6. Collecting tray; 7. Screw conveyor; 8. Conveyor driving gears; 9. Drive pulley; 10. Hand adjustment for tray position; 11. Frame; 12. Grain spreader; 13. Liftings outlet; 14 Grain outlet.

Step 9: Sifting
Polished Rice
Sifter
Sifted Rice
Rejection



Paddy
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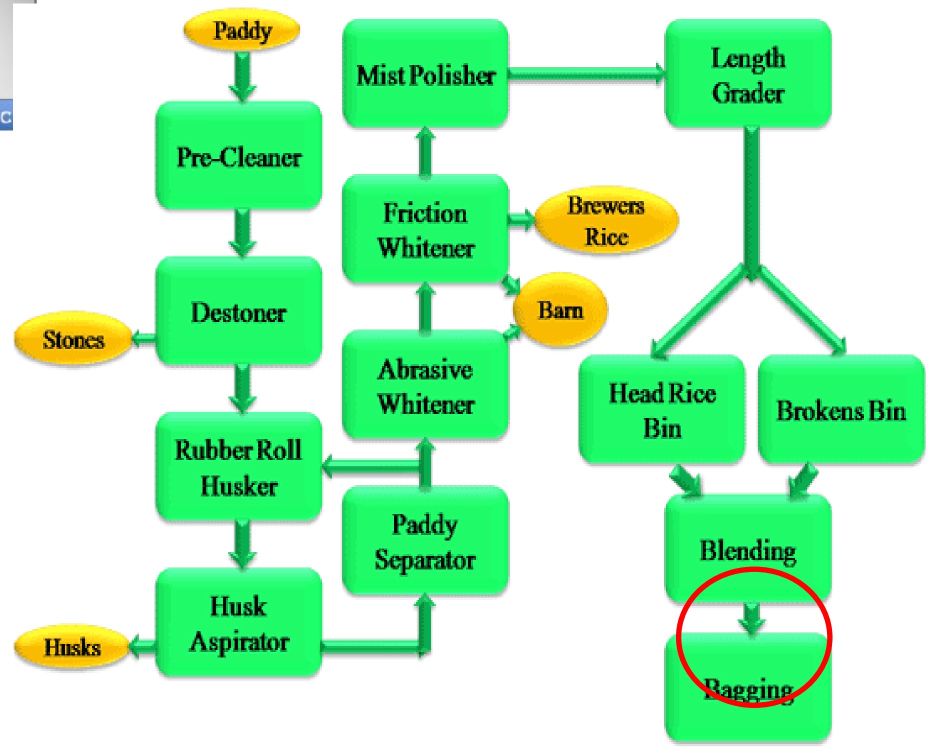
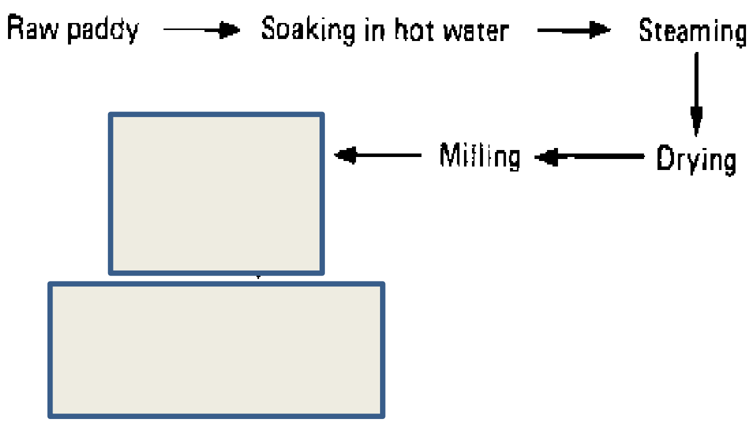
Step 11: Color Sorting

Step 12: Packing

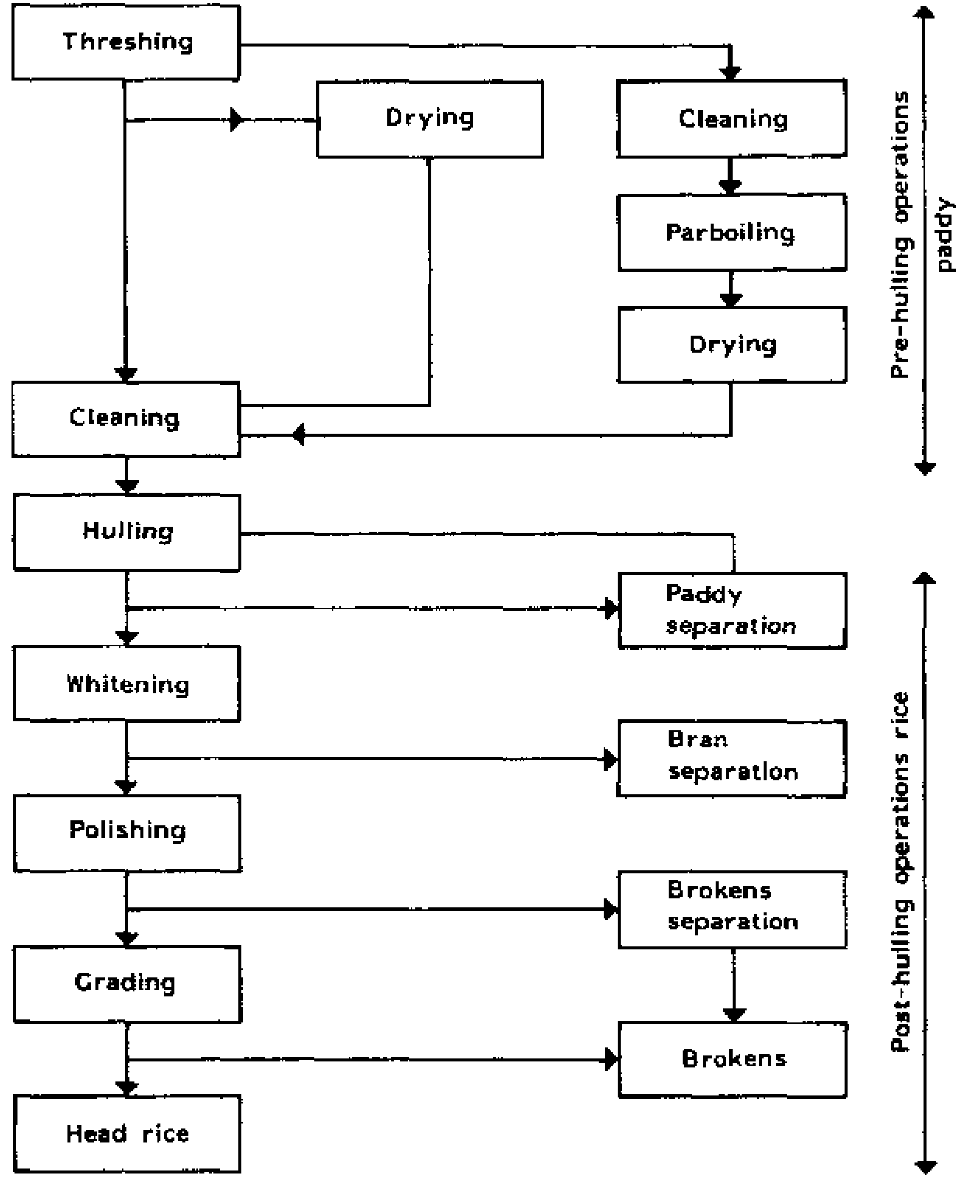


PARBOILED RICE

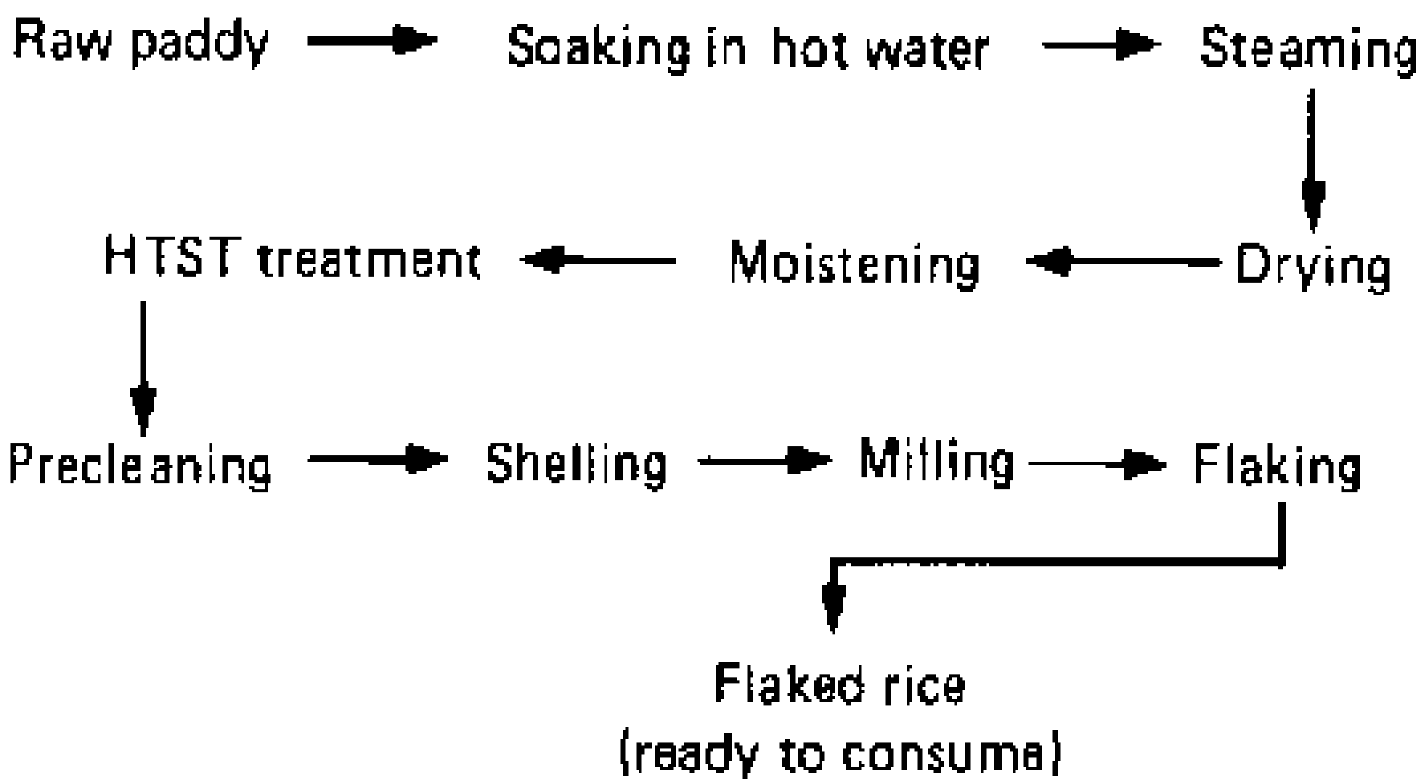
Basic



Detailed



FLAKED RICE


Raw paddy
Soaking in hot water
Steaming
Drying
Moistening
HTST treatment
Precleaning
Shelling
Milling
Flaking
Flaked rice
(ready to consume)