

## **Chapter 5 : Food Systems**

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### **General Aspects**

Food systems have traditionally been conceptualized as a set of linear activities from production to consumption, often depicted as a value chain. However, the growing focus on food security has broadened this understanding. Food security is a complex issue encompassing availability, access, and utilization, with multiple environmental, social, political, and economic drivers.

Food Systems are the people, places, and activities that bring us food. They make food available in diverse ways that influence and shape the choices we make about what to eat, when, and how. They are complicated and constantly changing – comprising a host of moving and interconnected pieces. They support many people’s livelihoods. Food systems encompass food supply chains, food environments, and consumer behaviour. They are driven by factors like economics, culture, technology and demography, as well as by institutional and other actions.

A food system is now understood as the **complete set of elements and activities related to food**. This includes the environment, people, inputs, processes, infrastructure, and institutions involved in producing, processing, distributing, preparing, and consuming food, along with the **socioeconomic and environmental outcomes** of these activities.

The evolution of food systems is shaped by five broad, interconnected categories of factors:

- **Biophysical and environmental factors:** Natural resources, ecosystem services, and climate change.
- **Innovation, technology, and infrastructure.**
- **Political and economic factors:** Policy direction, globalization, trade, food policies, land tenure, food prices and volatility, conflicts, and humanitarian crises.
- **Sociocultural factors:** Culture, religion, rituals, social traditions,.
- **Demographic factors:** Population growth, changing age structures, urbanization, migration, and forced displacement.

Food systems, their factors, actors, and components do not exist in isolation. They **interact with each other and with other systems** notably health, energy, and transport. These systems are interconnected and undergo continual adaptive cycles of growth, restructuring, and renewal.



**Figure 01 :** Food systems drivers.

## 1. Plant-based food systems

### 1.1. Primary vs. secondary metabolites: Functional roles in food

**1.1.1. Primary metabolites:** These are directly involved in the growth, development, and reproduction of the plant. In food, they are the **macronutrients**:

- **Carbohydrates (e.g., Starch in cereals):** Provide energy. Starch structure dictates glycemic index and cooking properties (e.g., waxy maize for smooth sauces).
- **Proteins (e.g., in legumes):** Provide amino acids. The **limiting amino acids** (lysine in cereals, methionine in legumes) are crucial for understanding protein complementarity in vegetarian diets.
- **Lipids (e.g., in soybeans, olives):** Provide energy and essential fatty acids. The fatty acid profile (saturated vs. unsaturated) determines oil stability and nutritional value.

**1.1.2. Secondary metabolites:** These are defense or signaling compounds. In food, they are **bioactive compounds** with health-promoting properties, though some can be anti-nutritional.

- **Polyphenols (e.g., in fruits, tea):** Their antioxidant activity is not just about "mopping up" free radicals in the body. They often exert effects by **modulating cell signaling pathways**. For example, resveratrol (grapes) activates sirtuin proteins involved in cellular stress resistance.
- **Glucosinolates (e.g., in broccoli):** When the plant tissue is damaged (chopped, chewed), the enzyme **myrosinase** converts them into bioactive **isothiocyanates** (like sulforaphane). This is why raw or lightly cooked cruciferous vegetables may offer different benefits than thoroughly cooked ones.

**Alkaloids (e.g., caffeine, solanine):** Can be stimulants or toxins. **Solanine** in green potatoes is a glycoalkaloid that can cause gastrointestinal and neurological disturbances, highlighting the importance of proper food storage and preparation.

## 1.2. Detailed analysis of food groups

### ❖ **Cereals: Beyond energy**

- **Protein quality:** Cereal proteins are often encapsulated within a protein matrix and stored in discrete bodies. Processing (milling, cooking) disrupts this structure, affecting digestibility.
- **The phytic acid problem:** Phytic acid (inositol hexaphosphate) strongly chelates minerals (Fe, Zn, Ca, Mg), forming insoluble salts in the gut and reducing their absorption. Processing techniques like **fermentation (sourdough bread)** and **malting** activate endogenous phytase enzymes that break down phytic acid, enhancing mineral bioavailability.

### ❖ **Legumes: The protein powerhouses with challenges**

- **Anti-nutritional factors (ANFs)**
- **Lectins (Hemagglutinins):** Bind to carbohydrate moieties on intestinal cell membranes, potentially disrupting nutrient absorption and causing cell damage. **Moist heat (boiling) effectively denatures them.**
- **Trypsin inhibitors:** Bind to and inhibit the digestive enzyme trypsin, reducing protein digestion. These are also **heat-labile.**
- **Flatulence factors (Raffinose-family oligosaccharides):** These  $\alpha$ -galactosides are not digested by human enzymes but are fermented by gut bacteria, producing gas. Soaking and discarding the water, or fermentation, can reduce these compounds.
- **Nutritional synergy:** The concept of **protein complementarity** (combining cereals and legumes) is based on filling each other's amino acid gaps, allowing for the synthesis of a complete array of body proteins.

### ❖ **Fruits and vegetables: The matrix effect**

The health benefits are not solely due to isolated vitamins or antioxidants. The **food matrix** the physical structure entangling nutrients plays a critical role in nutrient release, absorption, and bioactivity. For example, the **lipid-soluble carotenoids (like beta-carotene in carrots)** are much more bioavailable when consumed with a source of fat (e.g., olive oil).

### ❖ **Algae: Sustainable nutrient sources**

- **Iodine content:** Brown algae (kelp, kombu) are exceptionally rich in iodine. While essential for thyroid function, excessive intake can lead to thyroid dysfunction, demonstrating that "more" is not always better.
- **Unique Polysaccharides:** Carrageenan (red algae) and alginate (brown algae) are sulfated polysaccharides used extensively as **thickeners, gelling agents, and stabilizers** in food (dairy products, desserts). Their gelling mechanisms (carrageenan with potassium ions, alginate with calcium ions) are classic examples of food polymer chemistry.

## **2. Animal-Based Food Systems: Structure-function relationships**

### **2.1. Muscle to meat: The biochemical transformation**

- **Post-mortem biochemistry:** After slaughter, muscle undergoes **rigor mortis**. Glycogen is converted to lactic acid, lowering the pH. This pH drop affects protein structure, water-holding capacity (WHC), and tenderness. The rate and extent of pH decline are critical for final meat quality.
- **Protein Functionality:** The **myofibrillar proteins** (myosin, actin) are primarily responsible for water binding, gelation, and emulsification in processed meats. Their functionality is highly dependent on pH, ionic strength, and processing conditions (e.g., chopping temperature in sausage making).

## 2.2. Eggs: A Masterclass in Protein Functionality

- **Foaming (Egg White):** When egg white is whipped, **proteins denature** at the air-water interface, unfolding and forming a viscoelastic film that traps air. The **ovomucin** contributes to foam stability. Fat from yolk is a potent **foam inhibitor**, which is why separating eggs cleanly is crucial for meringues.
- **Emulsification (Egg Yolk):** **Lecithin (phosphatidylcholine)** is a powerful surfactant that lowers the interfacial tension between oil and water. **LDL (Low-Density Lipoproteins)** in yolk form a viscous, protective layer around oil droplets, preventing coalescence. This dual mechanism makes yolk an exceptional emulsifier for mayonnaise and sauces.
- **Coagulation/Gelation:** Upon heating, egg proteins unfold and aggregate, forming a continuous network that immobilizes water. Different proteins coagulate at different temperatures, allowing for fine control over texture (e.g., a soft custard vs. a hard-boiled egg).

## 2.3. Milk: A dynamic colloidal system

- **Casein micelles:** These are not simple aggregates but complex **colloidal structures** of casein proteins ( $\alpha_1$ ,  $\alpha_2$ ,  $\beta$ ,  $\kappa$ ) held together by **nanoclusters of calcium phosphate**.  $\kappa$ -casein, mostly on the surface, provides steric stabilization, preventing micelles from aggregating.
  - **Cheese Making:** Rennet (chymosin) specifically cleaves  $\kappa$ -casein, removing its stabilizing "hairy layer" and causing micelles to coagulate in the presence of calcium (**enzymatic coagulation**). Acidification (by lactic acid bacteria) dissolves the calcium phosphate nanoclusters, causing micelles to destabilize and aggregate (**acid coagulation**).

- **Whey Proteins:** These are **globular, heat-sensitive proteins**. When milk is heated above 70°C,  $\beta$ -lactoglobulin denatures and interacts with  $\kappa$ -casein on the micelle surface, which can affect rennet coagulation properties and yogurt gel strength.

### 3. Non-conventional food systems: The Frontier

This section addresses sustainability and food security.

**3.1. Single-Cell Proteins (SCP):** Grown on substrates like methanol, agricultural waste, or even methane. The biochemical challenge is **protein extraction and purification** from microbial cells, and ensuring the removal of nucleic acids (which can be high and lead to elevated uric acid).

**3.2. Insect Protein:** Insects have a high feed conversion efficiency. The main biochemical hurdles are **consumer acceptance** and the potential for **allergenicity** (cross-reactivity with crustacean allergens like tropomyosin).

**3.3. Cultured (Lab-Grown) Meat:** This involves **tissue engineering** of animal muscle cells. The biochemical focus is on developing cost-effective, food-grade **culture media (growth factors, nutrients)** and **scaffolding** to provide structure.

- **From processing to Sustainability:** Using plant proteins to replace animal proteins (nutrition/processing) can reduce the environmental footprint of the diet (sustainability).

Understanding food biochemistry is, therefore, the foundational science that allows us to navigate the interconnected challenges of producing nutritious, safe, sustainable, and desirable foods within our global food systems.

