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FOOD SECURITY

Course handout

SECOND YEAR AGRONOMY ENGINEERING

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PREFACE

This course booklet on Food Security has been prepared for second-year students in Agricultural Engineering as part of their academic and professional training. At this stage of your studies, you are beginning to connect fundamental scientific knowledge with real-world agricultural challenges. Food security stands at the intersection of agronomy, engineering, economics, environmental science, and public policy, making it a central theme in the education of future agronomists.

Today, ensuring food security is one of the greatest global challenges. Despite significant technological progress in agricultural production, millions of people worldwide still face hunger, malnutrition, and food insecurity. At the same time, agriculture must respond to climate change, water scarcity, soil degradation, biodiversity loss, and increasing population pressure. These complex and interconnected issues require well-trained engineers who are capable of designing sustainable, resilient, and efficient food systems.

This course aims to provide students with a comprehensive understanding of the concept of food security, its four pillars—availability, access, utilization, and stability—and the main factors that influence it at local, national, and global levels. Particular attention is given to the role of agricultural engineering in improving production systems, optimizing resource use, reducing post-harvest losses, strengthening supply chains, and enhancing system resilience.

Beyond theoretical knowledge, this booklet encourages critical thinking and a systems approach. Students are invited to analyze real case studies, interpret key indicators, and evaluate technological and policy solutions. The objective is not only to understand food security challenges but also to develop the capacity to contribute actively to their resolution.

As future agricultural engineers, you will play a decisive role in shaping sustainable food systems. Your technical expertise, combined with ethical responsibility and environmental awareness, will be essential in building a future where safe, nutritious, and sufficient food is accessible to all.

It is our hope that this course will strengthen your scientific foundation, broaden your perspective, and inspire your commitment to advancing food security in your professional career.

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CHAPTER 01 : CONCEPT OF FOOD SECURITY

1. FOOD SECURITY

1.1. DEFINITION OF FOOD SECURITY

The numerous attempts to define food security (FS) in research and policy usage demonstrate how malleable the idea is. Around 50 years ago, during the early 1970s worldwide food problems, the idea of food security was first proposed. There were over 200 published definitions of food security even twenty years ago, demonstrating the definition's contextually sensitive characteristics.

The current widely accepted definition of food security came from the Food and Agriculture Organization (FAO) annual report on food security “The State of Food Insecurity in the World 2001” : Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (1). The last revision to this definition happened at the 2009 World Summit on Food Security which added a fourth dimension – stability – as the short-term time indicator of the ability of food systems to withstand shocks, whether natural or man-made (2).

1.2. EVOLUTION OF THE CONCEPT OF FOOD SECURITY

Due to the severe volatility of agricultural commodity prices and the turbulence in the currency and energy markets at the time, the concept of food security was first centered on guaranteeing food availability and the price stability of staple foods in the early 1970s, a period of global food crises. Famine, hunger, and food crises necessitated a definition of food security that took into account the vital needs and actions of those who may be impacted and at risk. "The availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" was the definition of food security given at the World Food Conference in 1974 (3). This definition stressed understandably the need for increased production since protein-energy deficiency in 1970 was believed to affect more than 25% of the global population.

Later, as awareness of the food security crisis improved, the focus shifted from food availability to a broader strategy. The FAO definition of food security was expanded to include ensuring vulnerable individuals have access to accessible supplies as a result of a better understanding of how agricultural markets operate under stress and how at-risk populations end up without food. The idea of food security evolved from economic access to food. Then, "ensuring that all people at all times have both physical and economic access to the basic food that they need" became the new definition of food security.

The next development came in 1986 when the World Bank published its seminal report Poverty and Hunger. This introduced a time scale for food security by distinguishing between chronic food insecurity, associated with poverty, and acute, transient food insecurity, caused by natural or man-made disasters. These were reflected in a further extension of the concept of food security to include: “access of all people at all times to enough food for an active, healthy life”.

The next concept evolution happened in 1994 following the Uited Nations Development Program’s Human Development Report considering the requirements for human security. At this time, food security, which was within the larger framework of social security, entered the discussion of human rights. Since the studies on food security are often context specific, depending on which of the many technical perspectives and policy issues, this multidimensional and multifaceted operational construct had no coherent definition then. In an attempt to bring more unity to such complexity, a redefinition of food security was conducted through international consultations in preparation for the World Food Summit held in 1996, reflecting the complex interaction among, and between, individual, household, even to the global level. Food security, at all different levels, is achieved “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. In the mid-1990s, as the term “food security” evolved, the terms “nutrition security” and “food and nutrition security” also emerged. Food security is then considered as a subset of “food security and nutrition”.

The next development of definition of food security was redefined further in the “The State of Food Insecurity in the World 2001” by adding the social emphasis as cited above. It was recognized that addressing poverty is necessary but not alone sufficient to achieve this goal. Then at the 2009 World Summit on Food Security, the last official revision, which added the fourth dimension of stability to the concept of food security (FAO, 2009). More recently it has been suggested that sustainability be added as a fifth dimension to encompass the long-term time dimension.

1.3. FOOD SECURITY AND NUTRITION SECURITY

The definition of FS that has been in place for over three decades has made it clear that FS is a multidimensional construct that includes the following dimensions: *Quantity,* enough calories; Dietary *Quality,* nutritional value of foods; *Food Safety*, foods free of harmful microorganisms or other environmental contaminants; *Suitability,* culturally acceptable; *Psycho-emotional,* anxiety and feelings of deprivation; and *Social Acceptability,* socially acceptable methods for acquiring foods.

Nutrition status has been defined as “the assimilation and utilization of nutrients by the body plus interactions of environmental factors such as those that affect food consumption and food security”. Hence, it is a construct that needs to be assessed and understood by researchers, program evaluators, and policymakers at the level of the individual’s organism. Indeed, Smith presented a clear food and nutrition security multilevel framework adapted from Frankenberger and UNICEF, ranging from the global to the individual level to understand the strong relationship between FS and nutrition security and their distinct characteristics (Figure 1).

Extensive research involving experience-based FS scales has shown that in human societies, FS needs to be understood at the household level, and that it is a Social Determinant Of Health that, in turn, is strongly determined by socio-economic status and social class. FS relies on stable economic, physical, and social access to diverse, healthy, and nutritious foods that are culturally acceptable in the communities where the households are located. This access, in turn, depends on regional, national, and global availability of such foods. Currently, the global availability of these foods is constantly threatened by climate change and armed conflicts across the globe.

Nutrition security among individuals is determined by FS in combination with other social determinant of health, including healthcare access, housing, and other basic human needs such as water security.

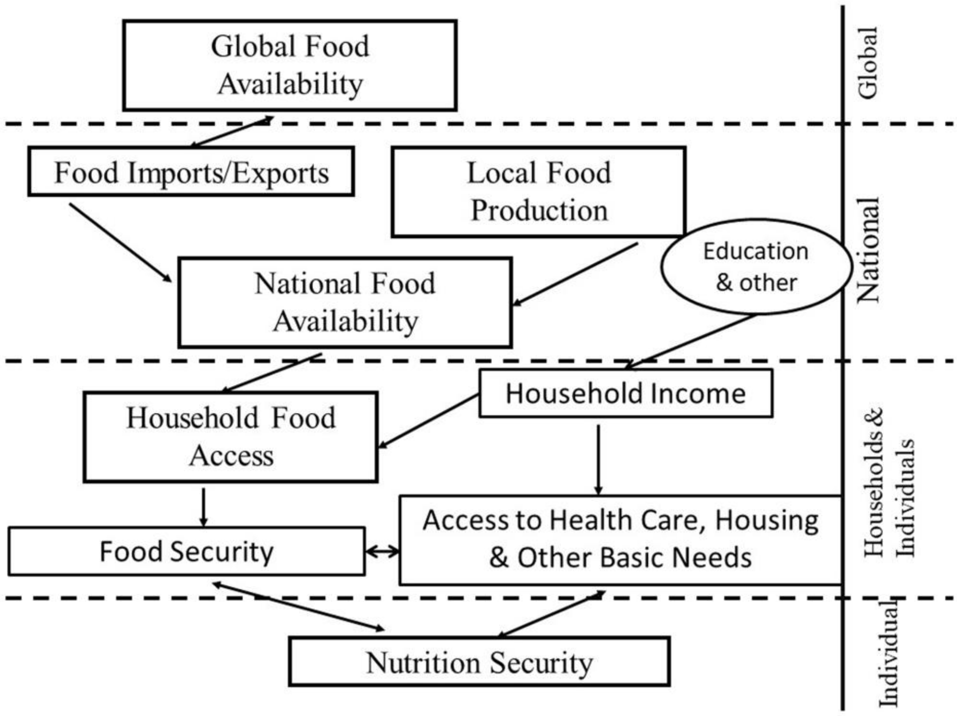

Figure 1 : The relationships between global food security, household food security, and nutrition security. (4).

Food and nutrition security sits right at the intersection of public health and human rights, as reflected in articles from the Uited Nations Charter on the Right to Adequate Food. For instance, *Articles 11 and 12* of the *International Covenant on Economic, Social, and Cultural Rights* along with children's rights to food, health, care, survival, and development; *Articles 6, 24, and 27 of the Convention on the Civil Rights of the Child* detailing the rights of mothers to adequate nutrition during pregnancy and lactation; and Article *12.2 of the Convention on the Elimination of all forms of Discrimination Against Women* highlight this intersection. These articles reflect the universal, indivisible, interrelated, and interdependence of the human right to food.

2. DETERMINANTS OF FOOD SECURITY

Food used to be called a basic human need along with water, peace, shelter, education and primary healthcare. It has also been called a prerequisite for health. Food security is now listed among the social determinants of health. It is clearly a determinant of a lot of things – life, health, dignity, civil society, progress, justice and sustainable developpement.

2.1. DIMENSIONS OF FOOD SECURITY

Four dimensions of food security have been identified according to the definition :

1) **Availability** of food produced locally and imported from abroad.

2) **Accessibility**. The food can reach the consumer (transportation infrastructure) and the latter has enough money for purchase. To such physical and economic accessibility is added socio-cultural access to ensure that the food is culturally acceptable and that social protection nets exist to help the less fortunate.

3) **Utilization**. The individual must be able to eat adequate amounts both in quantity and quality in order to live a healthy and full life to realize his or her potential. Food and water must be safe and clean, and thus adequate water and sanitation are also involved at this level. A person must also be physically healthy to be able to digest and utilize the food consumed.

4) The fourth domain of **Stability**, deals with the ability of the nation/ community/(household) person to withstand shocks to the food chain system whether caused by natural disasters (climate, earthquakes) or those that are man-made (wars, economic crises). Thus, it may be seen that food security exists at a number of levels. Availability - National; Accessibility – Household; Utilization – Individual; Stability – may be considered as a time dimension that affects all the levels. All four of these dimensions must be intact for full food security.

More recent developments emphasize the importance of **sustainability**, which may be considered as the long-term time (fifth) dimension to food security. Sustainability involves indicators at a supra-national/regional level of ecology, biodiversity and climate change, as well as socio-cultural and economic factors. These will affect the food security of future generations.

2.2. LINKING FOOD SECURITY TO SUSTAINABILITY

The notion of Sustainable diets links sustainability with food security to ensure holistic sustainable food systems, as can be seen from their respective definitions. Sustainable diets are defined as ones that "are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" . While "a sustainable food system "is a food system that ensures Food Security and Nutrition (FSN) for all in such a way that the economic, social and environmental bases to generate FSN for future generations are not compromised".

It has been internationally agreed that climate change is a threat to the sustainability of food security. However, the activities involved in food systems, account for some 20%–30% of all human-associated greenhouse gas (GHG) emissions, and, as such, contribute to climate change. There might be a trade-off relationship between decreasing humanassociated GHG and guaranteeing food security under current prevailing food system. Therefore, a systematic and integrated approach is needed, to meeting the short- and long-term requirements of FSN, meanwhile, to mitigating the negative environmental impact due to GHG from the activities involved in food system itself. Though what sustainable food systems actually look like is still unclear, our understanding is constantly evolving.

2.3. UNDERSTANDING OF FOOD SECURITY FROM PILLARS TO PATHWAYS

Food security is best considered as a causal, linked pathway from production to consumption, through distribution to processing, recognized in a number of domains, rather than as four "pillars".

In the 2009 World Summit definition on Food Security, the Summit used for the first time the phrase "four pillars of food security", representing the four dimensions, namely, availability, accessibility, utilization and stability, of food security. However, the visualization of pillars gives a rather misleading representation of the concept since the four dimensions are surely interrelated and interdependent, rather than static and separate. Pillars give no illustration of the linkage between the dimensions of food security.

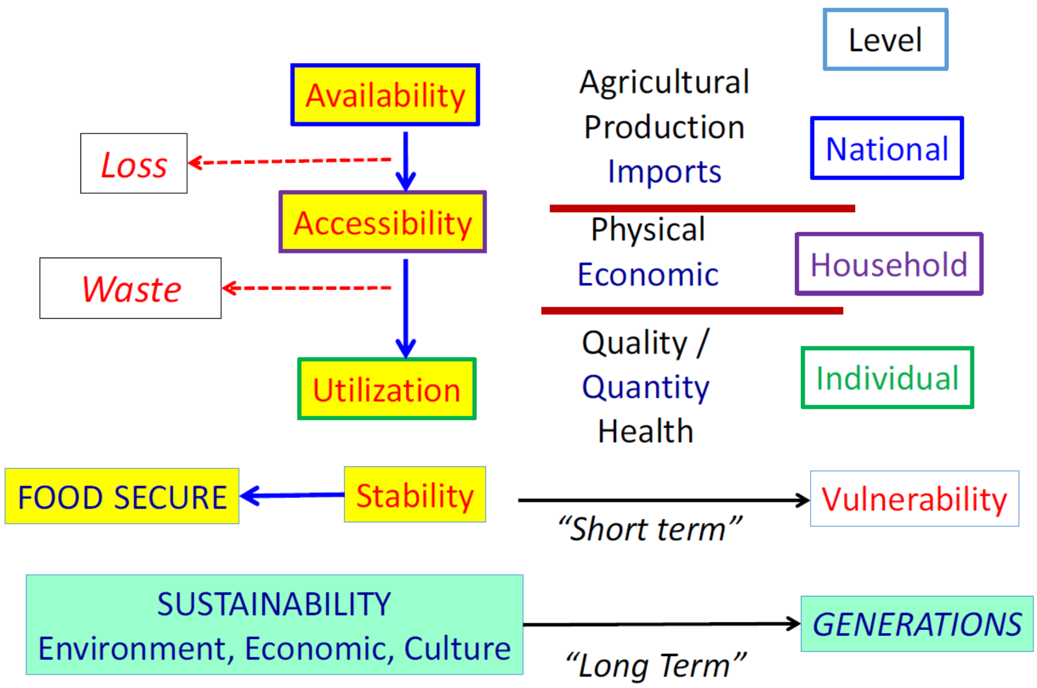

Figure 2. The pathway of the dimension of Food Security (5)

The weighting of the four dimensions is another problem faced by the visualization of four pillars, which directs to an impression of average weighting of 25% for each of the four dimensions. However, not all the elements in food security are of equal importance as implied by the pillar analogy. Their weightings are context and country specific. For example, in many developing countries, accessibility depends on the transport infrastructure which may limit the physical access to food; while in developed countries, economic access is the main barrier for food security. A scenario after a natural disaster, e.g., an earthquake, the availability, accessibility, utilization and stability are all major problems. In these different contexts, the weights of four dimensions should definitely not be equal.

Instead of pillars, a better analogy using a pathway to describe the relations among four dimensions of food security. This analog was used by The State of Food Insecurity in the World 2013, to show the links from food production (availability) to household (accessibility) to individual (utilization).

Accessibility contains physical (transport, infrastructure) and economic means (food purchasing power). It also involves socio-cultural access and preferences and its health effects and, with them the importance of social protection.

Stability thus emphasized the importance of bringing a time dimension, albeit short term, to food security. Apart from one-way pathways, the food security may also be considered circular, as there is a feedback loop from utilization to availability since human capital depends on optimal nutritional state for the workforce in agriculture and in all sectors of production.

These concepts are summarized in Fig. 2. An important insight from this figure is the importance of food losses (from agriculture, post-harvest and distribution) and food waste (from processing and consumption in the household and community). Worldwide these may amount to one-third of the food available and is an obvious target for improving food security. Reducing these amounts is a major challenge for securing world food availability in the future. From a systemic view obesity may also be considered a type of food waste.

3. FACTORS AFFECTING FOOD SECURITY

Food security is one of the most critical challenges facing humanity in the twenty-first century. It is not merely a question of producing enough food, but rather ensuring that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs for an active and healthy life. This definition, widely endorsed by international institutions such as the Food and Agriculture Organization, highlights the multidimensional nature of food security. For agricultural engineering students, understanding these dimensions is essential because engineering decisions directly influence agricultural productivity, postharvest systems, resource efficiency, and resilience of food systems.

Food security is commonly understood through four interrelated pillars: availability, access, utilization, and stability. Availability refers to the physical presence of adequate quantities of food supplied through domestic production, imports, or food aid. Access relates to the economic and physical ability of individuals to obtain food. Utilization concerns the nutritional quality of food, food safety, and the body's ability to absorb nutrients, which depends on health and sanitation conditions. Stability refers to the consistency of the other three pillars over time, ensuring that shocks such as climate events, economic crises, or conflicts do not disrupt access to food. Agricultural engineers influence each of these pillars through system design, technological innovation, and infrastructure development.

3.1. ENVIRONMENTAL AND NATURAL RESOURCE FACTORS

Form the foundation of food availability. climate change has emerged as one of the most significant threats to agricultural productivity. Rising temperatures, erratic rainfall patterns, increased frequency of droughts and floods, and extreme weather events reduce crop yields and destabilize production systems. Heat stress affects plant physiology, accelerates evapotranspiration, and reduces soil moisture availability. Changes in precipitation patterns can delay planting seasons and reduce germination success. For agricultural engineers, climate variability demands the development of climate-smart technologies, including efficient irrigation systems, soil moisture monitoring devices, and resilient greenhouse structures. Engineering models that predict weather patterns and optimize irrigation scheduling are increasingly important in reducing vulnerability to climate fluctuations.

3.2. SOIL QUALITY

Soil is another critical determinant of food security. Soil degradation through erosion, nutrient depletion, salinization, and compaction diminishes productive capacity. Unsustainable farming practices, deforestation, and overgrazing accelerate these processes. When soils lose fertility, crop yields decline and farmers are forced to expand into marginal lands, perpetuating environmental degradation. Agricultural engineers contribute by designing conservation structures such as terraces and contour bunds, developing precision agriculture technologies that optimize fertilizer application, and implementing soil moisture sensing systems that prevent over-irrigation and salinity buildup. Engineering solutions aimed at improving soil health directly enhance long-term food availability and sustainability.

3.3. WATER RESOURCES

They play a central role in agricultural productivity. Agriculture accounts for a significant proportion of global freshwater use, and increasing competition from industrial and domestic sectors places pressure on limited supplies. Over-extraction of groundwater leads to declining aquifers, while inefficient surface irrigation systems result in substantial water losses. In water-scarce regions, unreliable rainfall can lead to repeated crop failures. Agricultural engineers are responsible for designing and implementing water-efficient irrigation systems such as drip and micro-sprinkler technologies, which deliver water directly to plant roots and reduce evaporation losses. Automation systems that integrate weather forecasts, soil moisture sensors, and crop growth models allow precise control of irrigation scheduling, improving water use efficiency and stabilizing yields under variable climatic conditions.

3.4. BIODIVERSITY AND PEST DYNAMICS

It also influence food security. Monocropping systems, while efficient in mechanized agriculture, can increase vulnerability to pests and diseases. Climate change further alters pest distribution and life cycles, increasing the incidence of infestations. Engineers collaborate with agronomists to develop integrated pest management systems that combine mechanical, biological, and technological interventions. Remote sensing technologies, drone-based imaging, and artificial intelligence are increasingly used to detect early signs of crop stress and pest outbreaks, allowing timely interventions that protect yields without excessive chemical inputs.

3.5. ECONOMIC FACTORS

significantly affect food security, particularly through market access and price stability. Even when food is physically available, households may lack the purchasing power to obtain it. Price volatility in global commodity markets can dramatically affect food-importing countries. Fluctuations in staple crop prices can reduce affordability and increase vulnerability among low-income populations. Agricultural engineers contribute to mitigating these risks by improving supply chain efficiency. Designing robust storage facilities reduces postharvest losses and enables producers to store crops during periods of surplus, releasing them during shortages to stabilize prices. Cold chain systems preserve perishable products, expanding market opportunities and reducing waste. Logistics optimization models help reduce transportation costs and improve distribution networks, enhancing food access.

3.6. TRADE POLICIES AND GLOBALIZATION

Further shape food security outcomes. Countries heavily dependent on food imports are vulnerable to international supply disruptions. Export bans, tariffs, and geopolitical tensions can restrict availability and increase prices. Engineering solutions that promote local production, such as protected cultivation systems, hydroponics, and urban agriculture technologies, can reduce reliance on imports and strengthen national resilience. Vertical farming systems in urban areas, supported by controlled environment technologies, represent an example of engineering innovation addressing both availability and access in densely populated regions.

3.7. INFRASTRUCTURE DEVELOPMENT

Plays a crucial role in food systems. Poor rural roads, inadequate storage facilities, and unreliable electricity supply increase postharvest losses and limit farmers' ability to access markets. In many developing regions, substantial portions of harvested crops are lost before reaching consumers due to inadequate drying, storage, and transportation systems. Agricultural engineers design improved grain silos, hermetic storage units, and solar-powered drying systems to reduce spoilage and contamination. Infrastructure resilience is equally important; storage and processing facilities must withstand floods, storms, and seismic events to maintain stability in food supply.

3.8. SOCIAL AND INSTITUTIONAL FACTORS

That also shape food security outcomes. Governance structures determine land tenure systems, investment in agricultural research, and access to extension services. Secure land tenure encourages farmers to invest in long-term improvements such as irrigation infrastructure and soil conservation measures. Poverty and income inequality directly affect food access, as households with limited income may prioritize cheaper, less nutritious foods. Engineering solutions must therefore consider affordability and accessibility. Designing cost-effective, scalable technologies ensures that innovations benefit smallholder farmers as well as large commercial operations.

3.9. EDUCATION AND AWARENESS

Influence food utilization. Nutritional knowledge, food preparation practices, and sanitation conditions determine how effectively food meets dietary needs. Poor water quality and inadequate sanitation can lead to disease, reducing nutrient absorption and exacerbating malnutrition. Agricultural engineers working in interdisciplinary teams contribute to designing water purification systems, hygienic food processing equipment, and household-level preservation technologies that maintain nutritional quality.

3.10. TECHNOLOGICAL INNOVATION

Represents one of the most powerful drivers of improved food security. Mechanization increases labor productivity and allows timely planting and harvesting, reducing losses and enhancing yields. However, mechanization must be adapted to local contexts. In regions dominated by smallholder farms, compact and affordable machinery is more appropriate than large-scale industrial equipment. Renewable energy integration into irrigation and processing systems can reduce operational costs and environmental impacts.

3.11. BIOTECHNOLOGY AND CROP IMPROVEMENT

Influence food availability and stability. Improved crop varieties resistant to drought, salinity, and pests can maintain yields under challenging conditions. Agricultural engineers support these advances through the development of controlled-environment research facilities, precision planting systems, and optimized nutrient delivery mechanisms that allow improved genetics to achieve their full potential. Digital agriculture further enhances decision-making through the use of sensors, geographic information systems, and data analytics. Real-time monitoring of crop health and environmental conditions enables farmers to respond quickly to emerging challenges, improving productivity and resource efficiency.

Food safety and postharvest management are critical components of utilization and stability. In many regions, a significant percentage of food production is lost after harvest due to spoilage, pests, and inadequate storage. Contamination with mycotoxins and pathogens poses serious health risks. Engineering solutions such as controlled atmosphere storage, refrigeration systems, and solar dryers reduce losses and enhance food quality. By minimizing waste, these technologies effectively increase food availability without expanding production area.

Finally, stability integrates all other dimensions of food security. Economic crises, environmental disasters, and political conflicts can disrupt food systems. Engineers must therefore design systems that are resilient and adaptable. Diversified production systems, decentralized processing units, and modular infrastructure reduce vulnerability to shocks. Risk assessment models and early warning systems help anticipate disruptions and guide proactive responses.

Food security is a complex and dynamic issue influenced by environmental, economic, social, technological, and institutional factors. For agricultural engineering students, understanding these interconnected drivers is essential for designing sustainable and resilient food systems. Engineering interventions—whether in irrigation design, storage systems, mechanization, digital agriculture, or infrastructure development—play a central role in strengthening the four pillars of food security. By applying systems thinking and context-appropriate innovation, agricultural engineers can contribute significantly to ensuring that food systems meet the needs of present and future generations.

4. INDICATORS FOR MEASURING FOOD SECURITY

Food security is a multidimensional concept that requires precise and reliable measurement tools to assess its status across populations, regions, and time. According to the Food and Agriculture Organization, food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy life. Because this definition encompasses availability, access, utilization, and stability, no single metric can adequately capture the full picture. Instead, a set of complementary indicators is required.

Understanding food security indicators is essential. Engineers design irrigation systems, storage facilities, supply chains, mechanization technologies, and digital platforms that directly influence measurable outcomes. Evaluating whether such interventions improve food security requires familiarity with the indicators used at local, national, and global levels.

4.1. CONCEPTUAL FRAMEWORK FOR FOOD SECURITY MEASUREMENT

Food security measurement is grounded in its four pillars: availability, access, utilization, and stability. Each pillar requires distinct but interconnected indicators.

Availability indicators typically measure food production, supply, and stock levels. Access indicators focus on income, prices, and household purchasing power. Utilization indicators assess nutritional outcomes, dietary diversity, and food safety. Stability indicators evaluate vulnerability to shocks such as climate events, economic crises, and conflict.

International organizations such as the Food and Agriculture Organization, the World Food Programme, the World Health Organization, and the World Bank employ combinations of these indicators to monitor global and national food security conditions.

These indicators serve as benchmarks to evaluate the impact of infrastructure projects, irrigation systems, storage technologies, and production innovations.

4.2. INDICATORS OF FOOD AVAILABILITY

Food availability refers to the physical presence of food within a region or country. Several quantitative indicators are used to assess this dimension.

One fundamental measure is per capita food supply, typically expressed in kilocalories per person per day. This indicator is derived from national food balance sheets, which account for domestic production, imports, exports, and stock changes. A per capita supply below minimum dietary energy requirements signals potential food shortages at the national level.

Cereal yield, measured in kilograms per hectare, is another key availability indicator. It reflects productivity and technological advancement in crop production. Yield trends reveal the impact of irrigation systems, fertilizer use, mechanization, and climate variability. Agricultural engineers influence yield through improved water management, soil conservation, and precision agriculture systems.

Another important measure is the self-sufficiency ratio, defined as domestic production divided by domestic consumption. A ratio below 100 percent indicates reliance on imports. This indicator is particularly relevant for staple crops such as wheat, rice, and maize. Engineers working on national agricultural development projects often aim to improve this ratio by increasing productivity or reducing postharvest losses.

Postharvest loss percentage is also a critical availability indicator. Losses occurring during harvesting, storage, processing, and transportation reduce effective food supply. Technologies such as hermetic storage systems, cold chains, and controlled atmosphere facilities directly influence this metric.

Stock-to-use ratio measures the amount of food reserves relative to annual consumption. Higher ratios enhance resilience to supply shocks, contributing to stability.

4.3. INDICATORS OF FOOD ACCESS

Food access refers to households' ability to obtain food economically and physically. Income-based and price-based indicators are central to this dimension.

The poverty rate is widely used to assess economic access. Households living below national or international poverty lines are more vulnerable to food insecurity. Complementary measures such as household income per capita provide additional insight.

Food expenditure share is another commonly used indicator. It measures the proportion of household income spent on food. High expenditure shares suggest vulnerability, as households may be unable to absorb price increases without compromising consumption.

Food price indices track changes in the cost of staple foods over time. The global Food Price Index developed by the Food and Agriculture Organization monitors international price fluctuations. Rapid price increases often lead to reduced food access among low-income populations.

Household Food Insecurity Access Scale (HFIAS) is a survey-based indicator that captures household experiences related to anxiety about food supply, dietary compromise, and reduced food intake. It provides qualitative insights into access challenges.

For agricultural engineers, improvements in market infrastructure, transportation networks, and digital marketing platforms can reduce transaction costs and improve physical access to food markets.

4.4. INDICATORS OF FOOD UTILIZATION AND NUTRITION

Utilization indicators measure how effectively consumed food translates into adequate nutrition and health outcomes.

The Prevalence of Undernourishment estimates the proportion of a population whose habitual food consumption is insufficient to provide the dietary energy levels required for a normal active life. This is one of the most widely cited global hunger indicators.

Anthropometric indicators are critical in assessing nutritional status, particularly among children. These include stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age). These measures reflect chronic and acute malnutrition conditions.

Dietary Diversity Score measures the number of food groups consumed over a reference period. Higher diversity is associated with improved micronutrient adequacy.

Micronutrient deficiency prevalence, such as iron-deficiency anemia or vitamin A deficiency, provides additional insight into dietary quality.

Food safety indicators, including incidence of foodborne illnesses, reflect the effectiveness of processing, storage, and hygiene systems. Engineering interventions in cold chain design, packaging, and water sanitation directly influence these outcomes.

4.5. INDICATORS OF STABILITY AND VULNERABILITY

Stability indicators evaluate the reliability of food availability and access over time.

One commonly used measure is the variability of food production, calculated as the standard deviation of production levels over multiple years. High variability indicates vulnerability to climatic or economic shocks.

Import dependency ratio measures the proportion of food supply obtained from imports. While trade can enhance availability, excessive dependence increases exposure to global price volatility.

Climate vulnerability indices assess exposure to droughts, floods, and temperature extremes. Regions with high vulnerability require resilient infrastructure and adaptive agricultural systems.

Conflict and political instability indices also influence food security stability, as disruptions to markets and supply chains can severely affect availability and access.

Early warning systems, such as the Integrated Food Security Phase Classification, categorize food insecurity severity into phases ranging from minimal to famine. These classifications support rapid response planning.

4.6. COMPOSITE INDICES AND MULTIDIMENSIONAL MEASURES

Because no single indicator captures all dimensions, composite indices have been developed.

The Global Hunger Index, developed by the International Food Policy Research Institute and partners, combines undernourishment, child wasting, child stunting, and child mortality into a single score. It provides a comparative overview of national hunger levels.

The Food Insecurity Experience Scale, developed by the Food and Agriculture Organization, measures the severity of food insecurity at the household or individual level based on survey responses.

The Global Food Security Index, developed by the Economist Impact, evaluates affordability, availability, quality, and sustainability across countries.

Composite indices allow policymakers and researchers to track trends and compare countries, but they may mask local variations. Agricultural engineers must therefore complement national indices with field-level data.

4.7. ENGINEERING RELEVANCE OF FOOD SECURITY INDICATORS

Food security indicators provide measurable outcomes that guide engineering interventions. For example, if postharvest loss rates are high, investment in storage infrastructure becomes a priority. If cereal yields stagnate, irrigation and soil fertility management systems require improvement.

Indicators such as water productivity (kilograms of crop per cubic meter of water) are particularly relevant to agricultural engineers. Improving water productivity enhances both availability and sustainability.

Energy efficiency indicators in food processing systems contribute to reducing production costs and environmental impact. Monitoring carbon footprints of agricultural systems aligns food security goals with climate sustainability.

Digital monitoring platforms that integrate remote sensing data, yield estimates, and market price information enable real-time tracking of food security indicators. Engineers designing such systems play a critical role in improving data accuracy and responsiveness.

4.8. LIMITATIONS AND CHALLENGES IN MEASUREMENT

While indicators are essential, they have limitations. National-level data may not reflect intra-household inequalities. Survey-based measures may be subject to recall bias. Data gaps in low-income regions reduce reliability.

Moreover, food security is dynamic. Seasonal variations, economic shocks, and sudden climatic events can rapidly alter conditions. Therefore, continuous monitoring and multi-indicator approaches are necessary.

Agricultural engineers must understand that technological interventions should be evaluated using multiple complementary indicators rather than relying on a single metric.

Measuring food security requires a comprehensive framework that captures availability, access, utilization, and stability. Indicators such as per capita food supply, cereal yield, poverty rate, dietary diversity, prevalence of undernourishment, and production variability provide insights into different aspects of the food system.

Composite indices such as the Global Hunger Index and the Food Insecurity Experience Scale offer broader assessments but must be interpreted alongside detailed, context-specific data.

Mastery of food security indicators is crucial for designing, implementing, and evaluating interventions. Engineering solutions must ultimately translate into measurable improvements in yields, reduced losses, enhanced access, improved nutrition, and greater system stability. By aligning technological innovation with well-defined indicators, agricultural engineers can contribute effectively to building resilient and sustainable food systems.

CHAPTER 02 : FOOD INSECURITY

1. DEFINITION OF FOOD INSECURITY

Food insecurity is described as “limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways”. (6). Those individuals whose food intake decreases below their minimum calorie requirements are coming under the food insecure category, as well as the person who is physically not fit, or have some disease due to the lack of food and hunger or unbalance diet. (FAO. 2000)”. According to FAO Food Insecurity is defined as “a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and active and healthy life”. (FAO, IFAD. 2013).

Moreover, food insecurity is classified into three major categories by the FAO, those are :

(i) **Acute**: Severe hunger and malnutrition to the point that lives are in a significant threat immediately (e.g., famine).

(ii) **Occasional**: It is defined as existence of food insecurity due to a specific temporary circumstance.

(iii) (**Chronic**: the requirement of food needs is consistently or permanently under threat. Food insecurity is a multi-dimensional concept, and it affects every section of the population in different ways: children and mothers are also prone to food insecurity with various factors are overpopulation, gender inequality, lack of education and poverty. Overpopulated areas have the problem of food and can lead to malnutrition among children, especially in rural areas. The female child suffers more than the male child because they eat food after the male child due to male superiority. Lack of knowledge in women regarding nutrition, breastfeeding is also a concerning problem (Upadhyay & Palanivel, 2011). Generally, we assume that childhood food insecurity is caused by poverty, but there are other factors which also influence the children food insecurity, i.e., mother‟s physical and mental health, residential instability, living in a household without parents, no payment support foe child, mother‟s past and current substance abuse, and immigrant parents.

2. CAUSES OF FOOD INSECURITY

Food insecurity is both a cause and a consequence of violence, contributing to a vicious cycle or "conflict trap". Food security is critical for political stability. It is linked to increased risk of common failure, protests and rioting, communal violence and civil conflict. Violent conflicts, in turn, create food insecurity, malnutrition and in some instances famine. Thus, food insecurity can perpetuate conflict, although its effects depend on the context, with the most robust links evident in states that already have fragile markets and weak political institutions.

2.1. POPULATION GROWTH

Various scholars have different thought according to population growth and food insecurity. Malthus (6) gave an inverse relationship between the population and resources, a rapidly growing population become a burden on resources. So, he introduces positive checks (war, natural disaster, calamities) which occur if we do not control the population growth. British environmentalist, Sir Jonathan Porrit said that "*It's no good blaming climate change or food shortages or political corruption, continuing population growth in this region makes periodic famine unavoidable".* If we see, we find that the increase in population indirectly affects food security, but the effect of poverty is more than that. As we saw in the famine of Bengal in 1943. According to Nobel Laureate Amartya Sen (6), "starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there being not enough food to eat. While the latter can be a cause of the former, it is but one of many possible causes". We find that growth of population exacerbated the pressure on environmental degradation, social causes and climate change and further these factors pose the food insecurity problem to the state or region. Despite a sufficient amount of food availability, the issue of food insecurity is found in many areas.

2.2. CONFLICT AND POLITICAL INSTABILITY

Food insecurity can be both a cause and consequence of conflict and political instability. The relationship between conflict and food security affects each other as food scarcity leads to market collapse. As a result, food availability in the market decreases, which create greater havoc in public. Because of persistent conflicts and food insecurity millions of helpless people ready to migrate away from their homeland to a better place.

Population with poor health and nutrition are more responsible in the civil conflict in the food-insecure region. Food security is most critical for political stability. It is related to increased risk of democratic failure, protests and rioting, communal violence and civil conflict. As a result, these conflicts create food insecurity, malnutrition and in some cases famine.

2. 3. URBANISATION

The world population will increase from 6.7 to 9.2 billion from 2007 to 2050 in the urban areas of less developed countries (United Nations, 2008) (2, 13) and according to the FAO estimates that global food production should be increased up to 60 per cent by 2050 to meet population demands. It is projected that around two-thirds of the world's population will live in urban areas. It shows an expected decline in the rural population, which means the population at worldwide will need to produce more food with fewer farmers to meet the growing caloric demands in cities. This adds to an already problematic task for the world's farmers side by side, the agricultural land is decreased by the expansion of urban settlements. It should be emphasized that the future outlook in relations between urbanisation and food security is mixed. The global merging patterns in production and urbanisation and economic and human development provide opinions for an optimistic outlook in terms of sustainable urban development and the fight against hunger and under-nutrition.

2.4. CLIMATE CHANGE

It leaves a deep impression on food security in different ways. It affects the crops, livestock, forestry, fisheries, and aquaculture. Thus, climate change indirectly affects the socio-economic conditions of people through agriculture, market effects, etc. The social and economic disturbance is observed with the changes in agricultural incomes, food markets, prices and trade patterns, and investment patterns. At the farm level, they can reduce revenues. They can influence physical capital and force farmers to sell productive capital, for instance, cattle, field, to absorb income shocks. As a result, farmers become weak and have no money to invest. This problem directly affects the social impacts on farming households, limiting their capacity to face other expenses, such as health, education and standard of living. Safe water and sanitation facilities are also affected by climate change which may lead to diarrheal disease that can disturb the absorption of nutrients. Climate change can also increase different vector-borne diseases which can hamper people's physiological capacity to get necessary nutrients from the foods consumed and decrease labour productivity due to morbidity. The effects of climate change on food security are the consequences of climate changes themselves and the underlying vulnerabilities of food systems. They can be defined as “cascading impacts” from climate to biophysical, then economic and social, and to households and food security. At each level, vulnerabilities worsen the effects. The food-production system stability is a direct influence by the changes in climate variability. Increased frequency and intensity of the drought and flood would be a great threat to stability, whether the impact is domestic, local or through the global food market. The frequency and magnitude of food emergencies might increase, resulting from complex interrelations between political conflicts and migration in a context of increased competition for limited resources.

2.5. FINANCIALISATION OF FOOD

Financialisation of food refers to the increasingly significant role played by financial markets in the agri-food sector. The financialisaton process affected food systems in recent decades and financial actors, markets and motivations play a more significant role in society, and in all sectors of the economy. Food is being used as a commodity in international markets by speculators. The sole purpose of these speculators is only to earn profits. They have no direct interest in the foodstuffs, and they only used them as a source of income. Speculation is a valuable tool which is used for food price volatility. The result of these price hikes has been seen in the international food markets in 2007-08, 2010 and 2012, which show that how sudden price shocks can generate severe and prolonged food crises (6, 14). As many organisations assure that food is a human right and food cannot be used as a commodity for exploit.

2.6. KNOWLEDGE AND INFORMATION SYSTEMS

Food production and rural development in those countries which have food insecurity require suitable and up-to-date technologies which are very helpful in the transfer of technology for sustainable development, local food traditions and promote modernization of local production methods. To get advantage from these technologies will need proper training, education and development skills for local human resources (14). Knowledge and Information Systems are significant things to understand agriculture-related knowledge, safety net policies, environment, health and education, administration, marketing, and even political information. Knowledge improvement services, early warning systems and management information systems support all other efforts to address food security. Information systems are used exclusively to collect the performance of data that are related to crop production areas by using remote sensing and field data-gathering networks to provide early warning of emerging food insecurity situations.

03. CONSEQUENCES OF FOOD INSECURITY

The global food crises imperil the lives of millions of people in the most vulnerable communities, particularly in the countries where poverty, malnutrition and death from hunger are upswings day by day. The combined effect of rising food prices and lack of health care could be catastrophic for the poor. The countries experiencing constant food shortages and distribution problems leading to chronic and often widespread hunger amongst significant numbers of people. It effected on the social as well as economic well-being such as education, health, living of standard, behavioural challenges, etc. in the society. Therefore, food insecurity enables malnutrition and leaves children weak, vulnerable, and less able to fight common childhood diseases like diarrhoea, acute respiratory infections, malaria, and measles etc. Adolescents and adults also grieve adverse effects of food insecurity. Food insecurity can lead to low levels of energy, growth failure, delay in maturation, impaired cognitive ability, reduced capacity to learn, less ability to resist from infections and illnesses, reduced life expectancy, growth in maternal mortality, and low birth weight. Moreover, it may also result to political instability in the food insecure region because as food-insecure, people may be manifest the feelings of alienation, stress, and anxiety, and they may experience reduced productivity, decrease in work participation and school performance, and reduced income level. The household dynamics may also be disturbed due to the preoccupation with obtaining food, which may lead to anger, pessimism, and irritation among other vices.

3.1.POVERTY AND HUNGER

Poverty and food insecurity have a very close relationship. This view strongly stressed that food insecurity is a direct result of poverty. When you are hungry, you cannot do anything. As a result, you will continue to be poor and hungry. Hunger, poverty and disease are interlinked, with the contribution of hunger, the disease is generated. Hunger reduces the immunity against most diseases, and make prone to the illness. Poor people often cannot produce or purchase enough food to eat and so are more vulnerable to disease.

3.2. MALNUTRITION

Poor access to food and chiefly healthy food contributes to malnutrition in both aspects, undernutrition as well as overweight and obesity. Malnutrition increases the risk of low birth weight, childhood stunting, and anaemia in women of reproductive age, etc. Food insecurity can affect the child stunting, wasting and micronutrient deficiencies by negatively affecting the sufficiency of food consumption. A diet considered as insufficient intake of vitamins, protein, calories, and minerals will also obstruct foetal, infant and child growth and development.

VII.3. DEPRESSION

Food insecure people are very much prone to mental health problems. Poverty and mental health problems have a great linkage, basically emotional and psychological disorders. The study presents three principal findings. First, after controlling for conventional socioeconomic and socio-demographic variables, food insufficiency increases the risk of depression and predicts this risk better than measures of low income, the primary source of income, and education. Second, the negative effect of food insufficiency is not attributable to social resources disparities, even though these resources significantly reduce the size of the impact. Generally, we have seen that the problem of depression through food insufficiency is stronger in women than men, but this study shows that single fathers face more depression than any other groups, including single mothers from the food insufficient households.

Achieving food security in its totality continues to be a challenge not only for the developing nations but also for the developed world. The difference lies in the magnitude of the problem in terms of its severity and proportion of the population affected. In developed nations, the problem is alleviated by providing targeted food security interventions, including food aid in the form of direct food relief, food stamps, or indirectly through subsidised food production. These efforts have significantly reduced food insecurity in these regions. Similar approaches are employed in developing countries but with less success. Three other significant issues are emerging from the risk problems of food insecurity which must be a concern.

(a) The risk of temporary global food shortages

(b) The fast disappearance of the easy option of expansion of the cropped area to achieve supply expansion

(c) The increasing emergence of the food security problem as a problem of the urban poor in low-income countries.

4. COMBATING FOOD INSECURITY

Combating food insecurity requires far more than increasing crop yields. It demands integrated solutions that address production efficiency, resource sustainability, infrastructure, technology, policy, economics, and resilience to shocks. Agricultural engineers play a pivotal role in designing and implementing these solutions.

4.1. UNDERSTANDING THE NATURE OF FOOD INSECURITY

Food insecurity arises when one or more pillars of food security—availability, access, utilization, and stability—are compromised. Availability may be limited by low agricultural productivity or postharvest losses. Access may be restricted by poverty, poor infrastructure, or price volatility. Utilization may be undermined by poor food safety, inadequate storage, or insufficient nutrition knowledge. Stability may be threatened by climate change, economic crises, or conflict.

Combating food insecurity begins with diagnosing which pillar is weakest in a given region. For example, in drought-prone rural communities, the primary issue may be availability due to water scarcity. In urban food deserts, access and distribution systems may be the core challenges. Effective engineering solutions must target the specific weaknesses within the food system.

4.2. INCREASING AGRICULTURAL PRODUCTIVITY SUSTAINABLY

4.2.1. CLIMATE-SMART PRODUCTION SYSTEMS

Climate change significantly affects agricultural output through altered rainfall patterns, temperature stress, and extreme weather events. Engineering interventions to combat food insecurity must therefore enhance climate resilience. Climate-smart agriculture integrates water-efficient irrigation systems, soil moisture monitoring, crop modeling, and protected cultivation technologies.

Drip irrigation systems reduce water waste and improve crop water-use efficiency. Automated irrigation scheduling based on real-time sensor data optimizes water application, conserving resources while maintaining yields. Controlled environment agriculture, including greenhouses and vertical farming systems, enables year-round production and reduces vulnerability to external climate variability.

Precision agriculture further enhances productivity by using GPS-guided machinery, drones, and satellite imagery to apply fertilizers and pesticides accurately. This minimizes input waste, reduces environmental impact, and improves yield stability.

4.2.2. SOIL HEALTH RESTORATION

Soil degradation is a major contributor to declining agricultural productivity. Combating food insecurity requires restoring soil fertility through conservation engineering practices such as contour farming, terracing, and erosion control structures. Precision nutrient management systems allow targeted fertilizer application based on soil testing data. Conservation tillage and residue management systems help maintain soil organic matter and reduce erosion.

Engineering technologies that integrate soil sensors and data analytics provide farmers with real-time information on nutrient status, moisture levels, and compaction. By maintaining soil health, long-term productivity is sustained, supporting the availability pillar of food security.

4.2.3. ENHANCING WATER RESOURCE MANAGEMENT

Water scarcity remains a primary constraint in many agricultural regions. Efficient water management is therefore central to combating food insecurity. Agricultural engineers design irrigation systems that maximize efficiency while minimizing environmental degradation.

Micro-irrigation systems, including drip and sprinkler systems, significantly reduce water losses compared to traditional flood irrigation. Rainwater harvesting structures, farm ponds, and check dams increase water availability during dry periods. Wastewater treatment and reuse technologies offer alternative water sources for irrigation, especially in peri-urban agriculture.

Hydrological modeling tools enable engineers to predict water availability and optimize allocation among competing users. Integrated water resource management ensures that agricultural demands are balanced with environmental sustainability and domestic needs.

4.2.4. REDUCING POSTHARVEST LOSSES AND IMPROVING STORAGE

In many developing regions, a substantial proportion of harvested food is lost before reaching consumers. These losses directly reduce food availability and income for farmers. Combating food insecurity requires efficient postharvest systems.

Solutions include improved grain storage facilities, hermetic storage bags, temperature-controlled warehouses, and cold chain infrastructure. Solar-powered drying systems reduce moisture content in grains and prevent fungal contamination. Controlled atmosphere storage technologies extend the shelf life of fruits and vegetables.

Cold chain systems are particularly important for perishable commodities such as dairy, fish, and horticultural crops. By maintaining appropriate temperature and humidity conditions during transportation and storage, postharvest losses can be significantly reduced. Reducing waste is often more cost-effective and environmentally sustainable than expanding production.

4.2.5. STRENGTHENING FOOD DISTRIBUTION AND MARKET ACCESS

Food insecurity is frequently caused not by insufficient production but by inadequate distribution systems. Poor rural infrastructure, limited transportation networks, and inefficient logistics increase food prices and reduce accessibility.

Agricultural engineers contribute to combating food insecurity by designing resilient rural roads, optimizing transportation routes, and developing supply chain management systems. Digital platforms that connect farmers directly with consumers reduce intermediaries and improve income distribution. Blockchain-based traceability systems enhance transparency and trust in food supply chains.

Urban agriculture and peri-urban farming systems can shorten supply chains and improve access to fresh produce. Vertical farming technologies using hydroponics and LED lighting systems allow food production in densely populated cities, addressing access challenges while reducing transportation costs.

4.2.6. PROMOTING APPROPRIATE MECHANIZATION AND ENERGY SOLUTIONS

Mechanization improves productivity, reduces labor constraints, and enhances timeliness of farm operations. However, combating food insecurity requires mechanization strategies tailored to local contexts. Smallholder farmers often require low-cost, adaptable machinery rather than large-scale equipment.

Two-wheel tractors, modular attachments, and shared equipment models increase accessibility. Renewable energy integration, such as solar-powered irrigation pumps and processing units, reduces operational costs and enhances sustainability. Energy-efficient food processing technologies minimize waste and reduce carbon emissions.

Engineering solutions must prioritize affordability, maintainability, and local capacity building. Technologies that are difficult to repair or operate may fail to deliver long-term benefits.

4.2.7. INTEGRATING DIGITAL AGRICULTURE AND SMART TECHNOLOGIES

Digital agriculture has emerged as a transformative tool in combating food insecurity. Internet of Things sensors monitor soil moisture, temperature, humidity, and crop growth conditions in real time. Remote sensing and drone technologies provide early detection of pest infestations and nutrient deficiencies.

Data analytics platforms assist farmers in making informed decisions about planting dates, irrigation scheduling, and fertilizer application. Artificial intelligence-based forecasting systems predict crop yields and identify potential risks. These technologies improve resource efficiency and enhance resilience against environmental variability.

Mobile applications that provide market price information empower farmers to negotiate better prices and reduce exploitation. Digital financial platforms facilitate access to credit and crop insurance, strengthening economic resilience.

4.2.8. ADDRESSING NUTRITION AND FOOD UTILIZATION

Combating food insecurity involves ensuring not only caloric sufficiency but also nutritional adequacy. Engineering solutions in food processing and preservation help maintain nutrient quality. Fortification technologies add essential vitamins and minerals to staple foods. Hygienic processing systems reduce contamination risks.

Safe water supply systems and sanitation infrastructure support proper nutrient absorption and prevent foodborne illnesses. Engineers collaborate with nutritionists and public health experts to design community-level processing units and safe food handling systems.

Reducing foodborne pathogens and toxins through improved drying, storage, and packaging technologies enhances both food safety and utilization.

4.2.9. BUILDING RESILIENCE AND STABILITY

Food systems are vulnerable to shocks such as droughts, floods, economic crises, and political conflicts. Combating food insecurity requires resilient infrastructure and adaptive systems.

Flood-resistant storage facilities, drought-tolerant irrigation systems, and decentralized processing units enhance system stability. Risk assessment models and early warning systems allow proactive responses to potential disruptions. Diversified cropping systems reduce dependence on a single crop, minimizing vulnerability to pests and climate events.

Insurance schemes supported by predictive modeling provide financial protection for farmers during adverse events. Engineering tools that integrate climate forecasting with production planning improve preparedness.

4.3. POLICY, EDUCATION, AND MULTIDISCIPLINARY COLLABORATION

While engineering plays a critical role, combating food insecurity requires supportive policies and institutional frameworks. Secure land tenure, research funding, extension services, and infrastructure investment create enabling environments for technological adoption.

Agricultural engineers must collaborate with policymakers, economists, agronomists, and social scientists to design holistic interventions. Capacity building and technical training ensure that innovations are effectively implemented and maintained.

Education programs that integrate engineering principles with sustainability and food systems thinking prepare professionals capable of addressing complex challenges.

Combating food insecurity demands integrated, sustainable, and context-sensitive approaches. Agricultural engineers are uniquely positioned to contribute through innovations in irrigation, soil management, mechanization, storage, processing, digital agriculture, and infrastructure development. By focusing on productivity enhancement, loss reduction, efficient distribution, nutritional quality, and system resilience, engineers strengthen all pillars of food security.

The fight against food insecurity is not solely about producing more food—it is about designing smarter, more resilient systems that ensure equitable access to safe and nutritious food for all. Through interdisciplinary collaboration and sustainable engineering solutions, agricultural engineers can play a transformative role in achieving long-term global food security.

CHAPTER 03 : THE STATE OF FOOD SECURITY IN THE WORLD

Despite significant advances in agricultural technology, trade integration, and food production systems, hunger and malnutrition persist across many regions.

Globally, the state of food security is shaped by a complex interaction of environmental constraints, economic systems, demographic pressures, technological capacity, governance structures, and climate change. For agricultural engineering students, understanding the current global situation is essential because engineering solutions—irrigation systems, storage technologies, mechanization, digital agriculture, and infrastructure—are central to improving food system performance.

1. GLOBAL HUNGER AND MALNUTRITION TRENDS

Over the past several decades, global hunger declined significantly, particularly between 1990 and 2015. However, progress has slowed and, in some regions, reversed. Recent global assessments by the Food and Agriculture Organization, the World Food Programme, and the World Health Organization indicate that hundreds of millions of people worldwide remain undernourished (4).

The global food system produces enough calories to feed the global population, yet distribution inequalities and economic barriers prevent universal access. In addition to undernourishment, the world now faces a “triple burden” of malnutrition:

1. Undernutrition (stunting, wasting, underweight)
2. Micronutrient deficiencies (hidden hunger)
3. Overweight and obesity

While undernutrition remains prevalent in parts of Sub-Saharan Africa and South Asia, obesity and diet-related non-communicable diseases are increasing in middle-income and even low-income countries. This dual burden highlights that food security is not solely about production volume but also about dietary quality and food system structure.

2. FOOD AVAILABILITY: PRODUCTION AND RESOURCE CONSTRAINTS

2.1 GLOBAL AGRICULTURAL PRODUCTION

Global agricultural production has increased significantly due to improved crop varieties, mechanization, fertilizer use, and irrigation expansion. Major cereal producers—including China, India, the United States, and Brazil—supply a substantial share of global grain markets.

However, production growth has slowed in some regions due to yield plateaus, soil degradation, and climate variability. Land expansion opportunities are limited in many areas due to environmental constraints and urbanization.

Cereal yields have improved globally, but disparities persist between high-income countries and low-income regions. In some African countries, yields remain less than half of global averages due to limited irrigation, low fertilizer use, and restricted access to technology.

2.2 LAND AND SOIL DEGRADATION

An estimated significant portion of global agricultural land is affected by degradation, including erosion, salinization, nutrient depletion, and compaction. Soil degradation reduces productivity and increases vulnerability to drought and flooding.

Agricultural engineers must address soil conservation through erosion control systems, precision nutrient management, and conservation tillage technologies. Sustainable intensification is essential to increase output without further environmental damage.

2.3 WATER SCARCITY

Agriculture accounts for approximately 70% of global freshwater withdrawals. Increasing water scarcity threatens production in arid and semi-arid regions. Groundwater depletion is particularly severe in parts of South Asia, the Middle East, and North Africa.

Climate change exacerbates water stress by altering rainfall patterns and increasing evapotranspiration rates. Efficient irrigation systems, including drip and sprinkler technologies, are critical engineering responses to these constraints.

3. FOOD ACCESS: ECONOMIC AND SOCIAL DIMENSIONS

Even when food is available at the national or global level, households may lack economic access. Poverty remains one of the strongest determinants of food insecurity.

3.1 INCOME INEQUALITY

Income inequality limits access to nutritious food. In many low-income countries, households spend more than half of their income on food. When food prices rise, poor households may reduce both quantity and quality of food consumption.

Global food price volatility has periodically triggered food crises. International price spikes in staple commodities can rapidly increase hunger in import-dependent countries.

3.2 URBANIZATION AND FOOD ACCESS

More than half of the world's population now lives in urban areas. Urban food security depends heavily on efficient supply chains, cold storage systems, transportation infrastructure, and market organization.

Urban food deserts—areas with limited access to affordable fresh food—exist in both developed and developing countries. Engineers contribute to improved urban food security through logistics optimization, cold chain expansion, and vertical farming technologies.

3.3 TRADE AND GLOBALIZATION

International trade enhances global food availability but increases vulnerability to external shocks. Countries heavily dependent on food imports are exposed to global market fluctuations, geopolitical tensions, and supply chain disruptions.

Recent disruptions to global grain exports have highlighted the fragility of interconnected food systems. Diversification of supply sources and strengthening domestic production are strategic responses.

4. FOOD UTILIZATION: NUTRITION, HEALTH, AND FOOD SAFETY

Food utilization reflects the nutritional value of consumed food and the body's ability to absorb nutrients. This dimension is closely linked to health systems, sanitation, and food safety.

4.1 UNDERNUTRITION AND CHILD GROWTH

Stunting (low height-for-age) and wasting (low weight-for-height) remain significant challenges in parts of Africa and South Asia. These conditions reflect chronic and acute food insecurity, respectively.

Micronutrient deficiencies, particularly iron, iodine, and vitamin A deficiencies, affect billions globally. Addressing these deficiencies requires dietary diversification, fortification programs, and improved food processing technologies.

4.2 FOOD SAFETY CHALLENGES

Foodborne diseases remain a major global health concern. Poor storage, contamination during processing, and inadequate refrigeration contribute to spoilage and pathogen growth.

Postharvest losses are estimated to account for a substantial proportion of global food production. Engineering solutions—such as improved storage facilities, hermetic bags, and cold chain systems—can significantly reduce losses and improve utilization.

4.3 CHANGING DIET PATTERNS

Global dietary patterns are shifting toward higher consumption of processed foods, sugar, fats, and animal products. While this transition increases caloric intake, it often reduces nutritional quality, contributing to obesity and chronic diseases.

Engineering innovations in food processing must prioritize nutrient retention and safety while reducing energy consumption and environmental impact.

5. STABILITY: SHOCKS, CLIMATE CHANGE, AND CONFLICT

Food security stability refers to the ability of food systems to withstand shocks.

5.1 CLIMATE CHANGE

Climate change is one of the most significant long-term threats to global food security. Rising temperatures, altered precipitation patterns, and increased frequency of extreme events—such as droughts, floods, and heatwaves—affect crop yields and livestock productivity.

Climate-sensitive regions, including Sub-Saharan Africa and parts of South Asia, are particularly vulnerable. Engineering adaptation strategies include drought-resistant irrigation systems, climate-resilient crop infrastructure, and early warning systems.

5.2 CONFLICT AND POLITICAL INSTABILITY

Armed conflicts disrupt agricultural production, destroy infrastructure, displace populations, and interrupt trade routes. Conflict-affected regions often experience severe food crises.

5.3 ECONOMIC SHOCKS AND PANDEMICS

The COVID-19 pandemic demonstrated how global disruptions can affect labor availability, transport systems, and food supply chains. Economic downturns reduce purchasing power and increase vulnerability among low-income households.

Building resilience requires diversified production systems, strategic food reserves, and robust infrastructure.

6. REGIONAL OVERVIEW OF FOOD SECURITY

6.1. SUB-SAHARAN AFRICA

This region experiences the highest prevalence of undernourishment. Rain-fed agriculture dominates, making production highly vulnerable to climate variability. Limited mechanization and infrastructure constrain productivity.

6.2. SOUTH ASIA

Despite significant improvements in cereal production, malnutrition remains widespread. Water scarcity and land fragmentation are persistent challenges.

6.3. MIDDLE EAST AND NORTH AFRICA

This region faces severe water scarcity and high import dependence. Climate change intensifies vulnerability.

6.4. LATIN AMERICA AND EAST ASIA

These regions have made significant progress in reducing hunger, though inequality and environmental pressures remain concerns.

6.5. HIGH-INCOME COUNTRIES

While food availability is high, income inequality and dietary quality issues lead to localized food insecurity and rising obesity rates.

7. TECHNOLOGICAL INNOVATION AND FUTURE OUTLOOK

Technological advancements offer opportunities to address food insecurity. Precision agriculture, artificial intelligence, remote sensing, and digital supply chain management improve efficiency and reduce waste.

Controlled environment agriculture enables year-round production in urban areas. Renewable energy integration reduces dependence on fossil fuels in irrigation and processing systems.

However, technological adoption is uneven. Bridging the digital divide and improving access to finance and training are essential for maximizing benefits.

8. IMPLICATIONS FOR AGRICULTURAL ENGINEERING

Agricultural engineers are central to addressing global food security challenges. Key responsibilities include:

- Designing efficient irrigation systems
- Developing soil conservation technologies
- Reducing postharvest losses
- Improving cold chain logistics
- Integrating renewable energy into food systems
- Developing digital monitoring platforms

Engineers must adopt systems thinking, recognizing the interconnected nature of water, energy, land, and food systems. Sustainable design principles are essential to balance productivity with environmental conservation.

The state of food security in the world is characterized by paradoxes: sufficient global food production alongside persistent hunger; technological advancement alongside widening inequality; and increased efficiency alongside environmental degradation.

Climate change, economic volatility, population growth, and geopolitical instability present ongoing challenges. At the same time, engineering innovation offers powerful tools to improve resilience, productivity, and sustainability.

Understanding the global food security landscape is foundational. Effective engineering solutions must align with the four pillars of food security—availability, access, utilization, and stability—while addressing environmental and socio-economic realities.

The future of global food security will depend not only on producing more food, but on building smarter, more resilient, and more equitable food systems.

CHAPTER 04 : REALITY AND PROSPECTS FOR FOOD SECURITY IN ALGERIA

Food security in Algeria is a complex and evolving issue that reflects the country's geographic, economic, social, and environmental realities. Algeria is a large North African nation with significant agricultural potential but also pronounced constraints, including water scarcity, dependence on imports for staple foods, and climatic challenges. In recent years, food security has been elevated as a strategic national priority, with authorities actively pursuing measures aimed at increasing domestic production, reducing import dependence, and stabilizing food availability and prices. These efforts are set within broader national efforts to diversify the economy and improve rural development. Understanding the current state of food security in Algeria therefore requires an analysis of production systems, consumption patterns, policy interventions, and the structural constraints that shape outcomes. This context provides the critical background for designing resilient and sustainable technological solutions that address food system vulnerabilities.

1. NATIONAL FOOD AVAILABILITY AND PRODUCTION REALITY

Algeria produces a significant proportion of its food domestically, yet the country remains partially dependent on imported food commodities. According to recent official assessments, national agricultural production supplies a sizeable share of food needs, with authorities reporting that Algeria currently meets over 75% of its domestic food demand through local production. This figure reflects progress relative to past decades when domestic coverage was lower, yet it also underscores that a substantial portion of food consumption still relies on imports.

The agricultural sector in Algeria encompasses a varied range of crops and livestock. Staple grains such as wheat and barley are central to the national diet, while fruits, vegetables, dairy, and meat product sectors provide essential nutrition and employment. In strategic sectors like citrus and market gardening, production has increased significantly, contributing to both household food access and rural incomes. However, cereal production has historically been insufficient to fully cover domestic demand, leading to significant expenditure on imports of wheat and related products. For example, past analyses indicated that Algeria once sourced more than 80% of its soft wheat consumption from international markets, with purchases funded through oil revenues. This heavy reliance on imports exposes Algeria to global price volatility and foreign exchange fluctuations.

The government has set ambitious targets to increase cereal self-sufficiency and reduce reliance on imports. In recent agricultural seasons, authorities have reported exceptional harvests due to favorable weather conditions, improved seed varieties, and expanded cultivation areas, with official statements indicating that 2024–2025 may be a turning point toward greater self-sufficiency in grain production. This strategy emphasizes increasing both the area under cultivation and yield per hectare, supported by modern inputs and production practices.

Despite these gains, the diversity and sustainability of production remain constrained by structural factors. Soil quality, particularly in rainfed areas, remains a limiting factor for crop yields. Water scarcity in many regions, exacerbated by uneven rainfall distribution, restricts the expansion of irrigated agriculture and limits consistent high yields. Agricultural modernization, including mechanization and technological adoption, is ongoing but has yet to transform productivity at scale across all regions.

2. ACCESS TO FOOD AND ECONOMIC VULNERABILITIES

Food access in Algeria is influenced by economic conditions, demographic trends, and distribution infrastructure. Algeria's population has grown substantially over recent decades, increasing food demand and placing pressure on production systems. Urbanization has shifted consumption patterns, with higher demand for processed and perishable foods that require efficient supply chains and reliable storage infrastructure.

From an economic perspective, food access is closely linked to household income and price stability. High inflation and economic uncertainty can reduce the purchasing power of households, particularly among low-income groups. The government frequently intervenes to stabilize prices of key commodities through subsidies and strategic reserves. Strategic stockholding programs for essential products such as flour, milk, potatoes, and pulses are routinely mobilized, especially during periods of high consumption such as Ramadan, to ensure availability and prevent sharp price increases (15).

Rural infrastructure continues to pose challenges for equitable access. Many rural communities face limited physical access to markets due to poor road connectivity, inadequate rural transport, and insufficient storage facilities. These deficiencies increase postharvest losses and reduce market participation by smallholder farmers. Agricultural engineers are therefore confronted with the dual challenge of improving both production systems and the infrastructural networks that connect producers to consumers.

3. UTILIZATION, NUTRITION, AND FOOD SAFETY

Food utilization, defined as how effectively the body can absorb nutrients from food, is shaped by dietary diversity, food quality, and public health conditions. In Algeria, cereals represent a significant share of daily caloric intake, with wheat and wheat-based products being dietary staples. While cereals provide energy, they are less rich in micronutrients unless part of a diverse diet that includes fruits, vegetables, dairy, and animal proteins. Ensuring nutritional quality thus requires not only increased production but also efforts to diversify diet patterns and improve access to nutrient-rich food.

Food safety remains a priority, especially given the climatic conditions that can lead to spoilage and contamination in the absence of adequate storage and handling technologies. Technologies that improve food preservation and safe processing are critical to maximizing the utilization of available produce. Engineering interventions that ensure hygienic storage and distribution help reduce foodborne diseases and support improved nutritional outcomes.

4. STABILITY, CLIMATE RISKS, AND EXTERNAL DEPENDENCIES

Stability in food systems depends on the ability to withstand environmental, economic, and geopolitical shocks. Algeria is particularly vulnerable to climatic variability and long-term shifts in precipitation patterns. Most of the country's agricultural land is arid or semi-arid, making production heavily reliant on adequate rainfall and efficient water use. Climate change amplifies this vulnerability, leading to more frequent droughts, heat stress, and unpredictable rainfall, all of which threaten crop yield stability. Water resources, particularly in non-irrigated zones, are under increasing pressure, requiring improved watershed management and irrigation engineering to sustain agricultural output.

Strategic food import patterns also expose Algeria to global market fluctuations. Disruptions to global grain trade, whether due to conflict, maritime transport challenges, or commodity price spikes, can impact the availability and cost of staple imports. For example, disruptions in Black Sea grain exports have been noted for their implications on importer countries including Algeria. These dynamics underscore the importance of building resilient domestic production systems that can buffer against external shocks.

5. POLICY RESPONSES AND NATIONAL FOOD SECURITY STRATEGIES

The Algerian government has increasingly positioned food security as a strategic national objective. Leaders at the highest levels have publicly framed food security as essential to national independence and stability, encouraging investment and youth participation in the agricultural sector. Government strategies include supporting agricultural investment through subsidies, improving irrigation infrastructure, expanding arable land through concessions and reclamation projects, and enhancing seed availability via initiatives such as national seed banks.

Food security planning also integrates proactive production scheduling, strategic storage, and import licensing to manage supply during peak demand periods. These policies aim not only to ensure immediate availability but also to develop long-term resilience by strengthening domestic capacity. Research and innovation are increasingly recognized as vital, as evidenced by the recent establishment of a National Scientific Council on Food Security composed of experts tasked with guiding policy and supporting modern agricultural practices.

However, achieving food self-sufficiency remains an ongoing challenge. While some official projections have identified goals of reaching self-sufficiency in key staples in the near term, critics note that true food sovereignty involves not only production targets but also sustainable water and soil management, technological adoption, and systemic resilience beyond single crop objectives.

6. ENGINEERING AND TECHNOLOGICAL PRIORITIES FOR FOOD SECURITY

Algeria’s food security context highlights several priority areas for intervention. First, water management engineering is central to overcoming the constraints posed by aridity and climate variability. Efficient irrigation systems, rainwater harvesting, and reservoir management can improve water availability for crops and livestock. Precision agriculture technologies that optimize input use—fertilizers, pesticides, and water—also increase productivity while conserving resources.

Second, improving postharvest infrastructure and storage systems can substantially reduce losses and enhance year-round availability of food products. Cold chains, controlled-atmosphere storage, and improved handling facilities are particularly crucial for perishable goods like fruits, vegetables, dairy, and meat.

Third, strengthening digital agriculture platforms—such as crop monitoring systems, yield forecasting models, and farm advisory apps—can equip farmers with actionable data to make timely decisions and improve resilience against climatic and market risks.

Finally, integrating food processing and value-addition facilities closer to production zones can enhance local food systems by capturing more value locally, reducing waste, and creating employment opportunities in rural areas.

Algeria's food security situation reflects a mix of progress and persistent challenges. Domestic agricultural production has expanded and now meets a significant share of national food needs, yet reliance on imports continues for key staples. Structural constraints such as water scarcity, climate variability, infrastructure gaps, and economic vulnerabilities shape food availability and access. Government strategies have made food security a national priority, but achieving long-term stability and self-sufficiency will require sustained investment, technological innovation, and engineering solutions tailored to the country's environmental and socio-economic context.

Algeria's experience underscores the importance of integrating technical expertise with policy awareness and systems thinking. Engineering interventions in water management, production technologies, storage and postharvest systems, and digital platforms are critical to building resilient food systems that can sustainably meet the needs of Algeria's growing population.

CHAPTER 05 : NUTRITIONAL QUALITY

Within 10-15 years ago, food quality was considerably improved through use of changes in food legislation, legal requirements on food manufacturers and retailers. This way, consumers were protected from hazardous foods. Food quality may be defined as the features and characteristics required of a food product. These characteristics differentiate individual units of a product. In the food industry, food quality has to do with conforming with the intended purpose of the product, safety of the product and consumer acceptance. Consumers are the main arbiters of food quality. Apart from food safety, preferences for attributes of food quality may be heterogenous because consumers are heterogenous. In various countries, some bodies develop common criteria (such as quality control standards) and issue certificates to companies and also monitor the application of these standards by these companies. Internationally, there is Codex Alimentarius Commission. Packaging helps to maintain food quality by maintaining the characteristics with respect tocrispiness, loss of vitamins, aroma and flavour, breakage of product, lipid oxidation which leads to rancidity. Lipid oxidation is accelerated by free radical formation in foods which leads to a decline in food quality thereby decreasing consumer acceptability. To maintain food quality throughout its shelf life depend on packaging such as proper sealing of the packaging material especially around the seal.

1. DEFINITION OF FOOD QUALITY

Some authors have attempted to define food quality (Table 1), but generally, food quality has todo with the acceptability of food products by consumers.

Table 1: Definitions of food quality

No.	Definition	Reference
01	Food quality is a combination of attributes or characteristics of a productthat have significance in determining the degree of acceptability of theproduct to a user. These attributes include external factors such asappearance (size, shape, color, gloss, and consistency), texture, flavor,and internal composition (chemical, physical, microbial).Food	(7)

	quality also deals with product traceability (e.g., of ingredients),should a recall of the product be required. It also deals with labelingissues to ensure there is correct ingredient and nutritional information.	
02	Food quality is an expectation of consumers. To meet this consumerneed, every food business should develop and use an effective qualitycontrol program. Failure to meet consumer demand can cause a declinein product sales and profitability. A major product failure can totallydestroy a business	(8)
03	Quality has a vast number of meanings and can encompass parameters asdiverse as organoleptic characteristics, physical and functionalproperties, nutrient content and consumer protection from fraud.Furthermore, it can cover political and social issues such as wages paidto farm workers, geographical issues such as controlled appellations, andreligious issues such as halal and kosher.	(9)
04	Food quality has two facets i.e. it can be considered as the most welldefined or least well-defined concept in the food industry. None of themeasures like microbiological, nutritional, or physiochemicalcharacteristics serve adequate indices for food quality as food is aconsumer based evaluative/perceptual construct specific to a person, timeand place. ‘Consumer acceptability’ is the measurement that comesclosest to an adequate index. Sensory quality is the major factordetermining consumer acceptance for food products.	(10)
05	Food quality and safety are closely related to people's health and livingstandard, and the risk assessment of food quality and safety has greatsocial significance.	(11)

2. MEASUREMENT OF FOOD QUALITY

Measurement of food quality is essential ; quality indicators are not constant and the quality of a food changes over time. The most important quality-related changes are :

- Chemical reactions, mainly due to either oxidation or Maillard reactions.

- Microbial reactions: microorganisms can grow in foods; in the case of fermentation this is desired, otherwise microbial growth will lead to spoilage and, in the case of pathogens, to unsafe food.
- Biochemical reactions: many foods contain endogenous enzymes that can potentially catalyze reactions leading to quality loss (enzymatic browning, lipolysis, proteolysis, and more).
- Physical reactions: many foods are heterogeneous and contain particles. These particles are unstable, in principle at least, and phenomena such as coalescence, aggregation, and sedimentation lead usually to quality loss. Also, changes in texture can be considered as physical reactions, though the underlying mechanism may be of a chemical nature.

New methods of testing for food quality continue to be developed alongside improving traditional methods of analysis. The tools used, particularly those for analytical measurement, continue to get more sensitive, more specific, and faster, and the industries using these tools must keep up with these changes. All of these advancements set new standards and protocols on how the quality of foods and their ingredients are defined and monitored.

As food quality changes are often a function of physics-based phenomena, these changes can be well characterized through the use of mathematical modeling. Modeling approaches such as kinetic modeling, response surface modeling, and multivariate statistical modeling can all be used. This section covers the measurement of quality attributes for dairy products, meat and meat-based products, fruits and vegetables, seafood, and cereals and grains. Also covered in this section is the modeling of quality for these product groups.

3. STORAGE AND TRANSPORT REQUIREMENTS

Optimum food storage helps to preserve the quality and nutritional value of produced foods and helps to maximize the time that is available to sell said foods by preventing spoilage. Each class of food has different optimal storage conditions and can differ for both chilled and frozen states of that food. This section covers the storage and transport requirements for dairy products, meat and meat-based products, fruits and vegetables, seafood, and cereals and grains.

4. TRACEABILITY

Traceability is the ability to track any food through all stages of production, processing, and distribution (including importation and at retail). The general definition for traceability is that movements can be traced one step backward and one step forward at any point in the supply chain. For food processing businesses, traceability should extend to being able to identify the source of all food inputs such as:

- raw materials
- additives
- other ingredients
- packaging

Having an effective traceability system enables corrective actions (such as a product recall) to be implemented quickly and effectively when something goes wrong. When a potential food safety problem is identified, whether by a food business or a government agency, an effective traceability system can help isolate and prevent contaminated products from reaching consumers.

CHAPTER 06 : FOOD HYGIENE

Food hygiene is the conditions and measures necessary to ensure the safety of food from production to consumption. It is a fundamental requirement of any food process that the food produced should be safe for consumption. Food safety is a basic need but there is a danger that it may be overlooked in the development of effective and efficient processes. Food safety remains a critical issue with outbreaks of foodborne illness resulting in substantial costs to individuals, the food industry and the economy. Unsafe food has been a human health problem since history was first recorded, and many food safety problems encountered today are not new. Although governments all over the world are doing their best to improve the safety of the food supply, the occurrence of foodborne disease remains a significant health issue in both developed and developing countries.

Food can become contaminated at any point during slaughtering or harvesting, processing, storage, distribution, transportation and preparation. Proper food preparation can prevent most food borne diseases. More than 200 known diseases are transmitted through food.

The chances of food contamination and cross contamination become higher especially in the lower socio-economic classes due to unsatisfactory environmental conditions, poor personal hygiene, poor quality and insufficient water supplies, unhygienic preparation storage and feeding of foods. Food safety hazards are contaminants that may cause a food product to be unsafe for production. Lack of adequate food hygiene can lead to food borne diseases and death of the consumer. Contaminated food presents one of the most common cause and major contributor to gastrointestinal illness (e.g. acute diarrhea, nausea, vomiting and abdominal pain), compromised nutritional status and less resistance to disease and loss of productivity in the world.

1. FOOD CONTAMINATION DURING FOOD PROCESSING

The food processing steps are shown in (Fig 3) The presence of unwanted materials such as dust and particles during the manufacturing and transportation time is called contamination. The term contaminants include any unwanted matter that is found in the product. These contaminants affect the quality of the product or the process. It has been demonstrated that food contamination, either from microbiological or chemical origin, is the highest concern for consumers. Sample treatment devices, such as micro extraction techniques able to remove the matrix interferences and to concentrate the analyses from the sample, have been developed and proposed as powerful tools for food analysis. But the task of identifying the contaminants, either those coming from the food production, the food processing or the packaging is still a challenge. The information about the likely contaminants coming from each step of the food processing is essential.

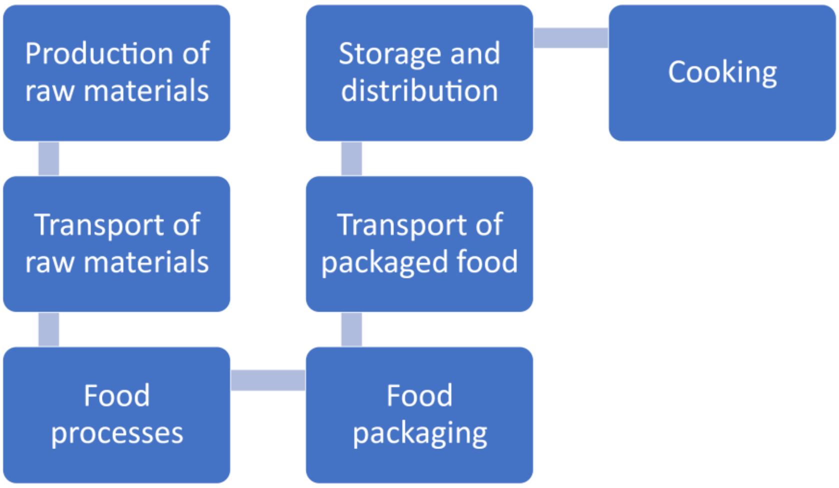

Figure 3. Steps of Food Processing (12)

1.1. EXTERNAL RAW FOOD CONTAMINATION

Industrial growth, advances in the use of agrochemicals, or the urban activities can contribute to the presence of food contaminants. An important focus of food contaminants is the use of fertilizers and pesticides, since they can cause health problems if they are consumed by humans. Some studies detected pesticide residues in fruits and vegetables and also some derivatives with also adverse effects, such as metabolites from organochlorine pesticides have been found in fatty food Heavy metals such as cadmium, lead, mercury, and arsenic, recognized as toxic, can be present in air, soil, and water, and therefore they can be transferred to foodstuff. The analysis of heavy metals has been performed in several foodstuffs such as honey, spinach, potatoes, fish and tea.

1.2. CONTAMINATION DURING FOOD TRANSPORT

Food contamination can also take place during transportation. It can be cause by from vehicle exhausts of petrol and diesel or because a cross contamination in the vehicle used for food transportation. This cross-contamination can create a serious risk for food safety. In 1999, a major illness in the European Economic Community was attributed to fungicide contaminated pallets used for transportation and storage of food packaging materials. Long distance transport ship has been also several times affected by cross contamination from chemicals used for disinfection or from other sources. The contamination of food can take place by permeation of naphthalene, methyl bromide, toluene, ethyl benzene and ortho par a xylenes through a theoretical high barrier material.

1.3. CONTAMINATION CAUSED BY CLEANING PROCESSES

Cleaning and disinfecting during food processing eliminate the presence of possible microorganisms and therefore, they are crucial to reduce food contamination. Chemicals used as cleaners or disinfectants must be appropriate for food contact surfaces and need to be accepted by the legislation. Products such as glass cleaners or some metal cleaners can't be used because they might leave unsafe residues. The addition of sanitizers in quantities far above permitted levels could leave some residual concentration on treated materials or food even in minimum processed fruits and vegetables, and therefore, to quantify the residual chemicals present in the food is important in order to certify that they have been completely removed. Some common surfactants are quaternary ammonium compounds such as dodecyl-trimethyl-ammoniumchloride and nonionic surfactants such as stearyl alcohol ethoxylate. Factors affecting its elimination from different materials surfaces, such as rinsing time or water temperature.

1.4. CONTAMINATION DUE TO HEATING STEPS

The use of high cooking temperatures in combination with external factors, can lead to the formation of toxic compounds, which can have a deleterious effect on the food quality and safety. Certain toxics compounds (e.g., acrylamide, nitrosamines chloropropanols, furanes or PAHs) can be formed in foods during their processing, such as during heating, baking, roasting, grilling, canning, hydrolysis or fermentation. Frying is by far the cooking process that can act as a generator of a wide variety of toxic compounds into the food. Flavor substances are produced by reactions of oxidized frying oil with proteins and other sulfur and nitrogen substances in the food. Various compounds are released from the food into frying oil, enhancing discoloration or off-flavors. Pigments present in frying oil may also be adsorbed on the surface of fried food. Certain processing contaminants, such as nitrosamines, can be formed by interaction of natural food components with food additives during heating. Nitrosodimethylamine has been detected in certain foods as a result of the direct-fire drying or roasting processes. Nitrosamine formation during vapor or boiling cookings (which implies lower temperatures, 100ºC) are lower than the amount formed during frying, roasting or grill cooking. The production of mutagens is much lower in absence of fat. Model mixtures containing Maillard precursors such as glycine, glucose and creatinine were heated in contact with iron salts and fats.

Microwave heating is becoming an increasingly used process for heating foodstuffs in home and in some industrial sectors. A common characteristic of the microwaving cooking is that the food is cooked in the packaging material (wrapping film, container) in the microwave oven. Such microwavable packaging materials include plastics, paperboard and composites, which during microwave cooking many of their components (i.e., plasticizers, antioxidants, monomers, stabilizers, etc) can migrate from the package into the food. This results in a decrease of food quality and food safety.

1.5. FOOD PACKAGING

Food packaging provides many advantages such as physical protection, barrier protection and it also allows a better food preservation that will increase the shelf life of the product. The direct or indirect contact between the food and the packaging material can end up the transference of these substances from the packaging to food, in a phenomenon called migration. Migrants can pose a health risk for consumers if they have a toxic effect. To protect the consumers, there is a strict legislation in FDA, Europe, Mercosur, Australia and Euroasia as well as in many countries to avoid the contamination from the materials and articles to the food in contact with them.

1.6. CONTAMINATION DURING FOOD STORAGE

Food storage conditions are key parameters in food quality and safety. Proper storage extends the shelf life of food, which depends on the food type, packaging and storage conditions, particularly temperature and humidity. Organoleptic changes should not occur during food storage and therefore packaging materials used for long term storage should exhibit very good barrier properties. Moisture can lead to the breakdown of some packaging materials (e.g., paper degradation and metal rusting). The optimal range of temperature is the cool to moderate range, between 4 and 21^0C. Direct sunlight can speed deterioration both on the food and on the packaging. Depending on the barrier properties the transference of compounds through the packaging material will be different as was demonstrated.

2. FOOD SAFETY HAZARD

Food safety hazards are contaminants that may cause a food product to be unsafe for production. Hazards are defined by Codex 1997 as follows: “Hazard: a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect”. Hazards may enter a food product from its ingredients or may contaminate during processing or handling. It is important to understand the likely hazards that might be encountered in the chosen ingredient types, or that might be present in the processing environment. This allows the development team to identify the best ways to control these hazards, either by preventing their entry to the process, destroying them or reducing the contamination to a level. It is no longer process a food safety risk. This information on likely hazards and proposed control options should link with the prerequisite good manufacturing practice programs and HACCP systems to ensure everyday control is established in the manufacturing operation.

Ways to maintain food safety and hygiene (17) :

A. Good Manufacturing Practices (GMP).

B. Sanitation Standard Operating Procedure (SSOP).

C. Good Hygiene Practices (GHP).

D. Hazard Analysis of Critical Control Points (HACCP).

3. GOOD MANUFACTURING PRACTICES (GMP)

GMP have existed since the 1970s, but were formalized in different countries only in the mid-1990s. GMP are actions applied to the production of food, drug, and medical equipment production. GMP are based upon four points : exclusion, removal of undesirable and foreign matter, inhibition, and destruction of undesirable microorganisms. The elements that make up GMP are : the facility and its surroundings, the staff, cleaning and sanitization processes; equipment and utensils; processes and controls; and storage and distribution. Analysis and control of these elements by the GMP program aim at the production of high-quality foodstuffs GMP are one of the ways to control foodborne diseases. Industries that have adopted GMP programs obtained the following results, among others: better quality of foodstuffs; safer products; decreased incidence of consumer complaints ; better, more agreeable, cleaner and safer working environment; greater employee motivation and productivity; and improved psychological conditions. The implementation of GMPs is a continual process based upon the management of the PDCA (plan, do, check, and act) cycle.

4. SANITATION STANDARD OPERATING PROCEDURE (SSOP)

SSOP are written procedures developed and implemented in a facility to prevent direct contamination or adulteration of the products. SSOP include a complete description of the specific activities required to maintain utensils and equipment free of pathogenic microorganisms and minimal deteriorating microbiota, preventing the contamination of foodstuffs that get in contact with these utensils and equipment. The facility is required to maintain these written procedures on file, and these must be available to regulating or government bodies upon request. The following central directives of SSOP have been determined considering the potential sources of contamination: cross-contamination from raw to cooked products (e.g., surface contact with contaminated foods); contact of product with nonpotable water (e.g., condensation on exposed products) or other unsafe substances; contact with nonfood substances (e.g., pesticides); contact with airborne substances; diseases or inadequate hygiene of handlers; foreign matter; and pest control.

5. GOOD HYGIENE PRACTICES

Good hygiene practices (GHP) are the procedures and practices undertaken with the use of best practice principles. European Commission (EC) Regulation No 852/2004, defines food hygiene as the measures and conditions necessary to control hazards and to ensure fitness for human consumption of a food stuff taking into account its final use. GHP are generally called the prerequisite measures upon which other Food Safety and Quality Management Systems are built. They include an exhaustive list of measures and among them is staff personal hygiene and training. Food hygiene training is a legislative requirement that ensures that safety practices are used and maintained in food preparation environment. lack of success in hygiene training were methods used, demographics of trainees and their preparedness to learn, lack of supervision after training, absence of refresher programmes and lack of resources to implement knowledge gained in areas with economic challenges.

6. HAZARD ANALYSIS OF CRITICAL CONTROL POINTS (HACCP)

It is a systematic set of activities used to control food production in order to ensure food safety and prevent changes in foodstuffs. The system is based upon the use of control practices in given production steps where there is a greater probability of occurrence of health hazards. The prerequisite programs for HACCP implementation in food industries are GMP and SSOP, which involve several aspects of the food industry, such as physical structure and maintenance, water supply, personal hygiene, pest control, sanitization techniques and equipment, calibration of instruments, and quality control of raw material and ingredients, among others. Prerequisite Programs (PRPs) provide a hygienic foundation for the HACCP system by enabling environmental conditions that are favorable for the production of safe food. The system is applied to all steps of the food chain, from the production of raw material to the final product, including aspects related to consumer demands, such as processed products that do not have negative effects on their health. The HACCP system uses predetermined concepts and terms that include :

- Hazard: Unacceptable biological, physical, or chemical contamination that renders food inadequate for consumption.
- Risk: Estimated probability of the occurrence of a hazard.
- Critical control point (CCP): Production step where preventive measures are applied in order to maintain the given product under control, and to eliminate, prevent, or reduce risks to the health of the consumer.
- Critical limit: Value or attribute determined for each variable related to a critical point. Noncompliance leads to risks to consumer health. Critical limits are determined by guidelines or legal standards, specialized literature, practical expertise, previous surveys, internal company regulations, and other sources.
- Corrective action: Immediate and specific actions to be put into place when noncompliance with critical limits occur.
- Validation: Use of supplementary tests or review of monitoring records to determine if the HACCP system is functioning according to the plan.
- Decision tree: Logical sequence used to determine if a raw material, ingredient, or process step is a CPP for a given hazard.

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