AN OVERVIEW OF THE FOOD SYSTEM

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Summary

The global food system consists of agricultural production, processing, distribution, retail operations, consumption, and waste management. Technologies used throughout the food system vary with the degree of industrialization. In many parts of the world, the food system is complex with elaborate food processing and distribution operations. In other areas, the food system might be as simple as transport of raw goods from the farmer to the consumer.

The current food system does not adequately meet the need of the world. Approximately 1200 million people live on less than US $1 a day. In 2005, an estimated 1.8 million people died of diarrheal diseases annually. These statistics point to a need for modification of existing policies and regulations to improve safe food production and efficient food distribution. Other topics of concern in world agriculture today include food safety and intentional contamination, the long term impact of genetic modification of crops, food security and ensuring a sufficient and nourishing food supply, and traceability of food items in commerce. This chapter discusses these areas and the impact these issue may have on agricultural sustainability across the world.

1. Introduction

The world's food system consists of agricultural production, food processing, distribution, and retail, in addition to waste, energy and environmental management subsystems. While each subsystem is quite complex, the overall system can be characterized at local, regional, national, or global levels in relatively straightforward terms and with relatively simple models. This chapter provides an overview of the current status of food systems, their interaction with the environment, and an assessment of the sustainability of current agricultural practices and impacts on poverty and community development.

1.1. Current Problems Facing the Food System

It is critical to improve food production and distribution systems to avoid rampant poverty and starvation. At present, the global food system does not adequately meet the needs of the world's population. About 820 million people are living with hunger. Ironically, the food supply is the least secure for agricultural workers who are among the most malnourished and impoverished individuals. Chronic infrastructure problems with the food system are a major underlying cause of this problem including: a lack of inputs such as available clean water and energy, seed, fertilizer, and implements. Soil degradation and either inappropriately developed or poorly capitalized production and distribution systems result in inefficiencies even when inputs are adequate. A lack of suitable farm-to-market transport, financing and communications are other critical factors which negatively impact the food system at all levels.

Water management is potentially the greatest risk to food security. In much of the developing world, over two-thirds of the available water resources are committed to irrigation. This is a particular concern in sub-Saharan Africa where water resources are oversubscribed by up to 70%, a situation currently facing Botswana. Agricultural and food processing practices have contributed to inadvertent detrimental changes to the natural environment including desertification, eutrophication of bodies of water, deforestation, flooding, and silting that has led to reduced agricultural productivity in large parts of Asia, Africa, Central and South America and Australia.

The risk of food and waterborne food associated disease remains a major problem in much of the world. Although there are generally accepted international water and food hygiene standards it is difficult to implement these in much of the world due to poor

infrastructure, particularly for the recovery, production and delivery of potable water. The impact of this lack of safe water and the resulting introduction of pathogenic bacteria and viruses has an alarming effect on public health. It is estimated that 1.8 million people die from diarrheal diseases annually (WHO 2002b). Cases of food and water associated food and water borne illness are greatly underestimated due to the lack of surveillance in most countries and the narrow breadth of current surveillance networks in the countries where public health surveillance systems do exist. Developing sources of safe water for food processing, and then increasing the use of suitable technologies for food production, processing, storage, and distribution are vital for ensuring a microbiologically safe food supply for consumers as well as a food supply that is stable during storage and distribution after the immediate harvest season has passed.

Over half of the population in the developing world is involved in agricultural production on either a subsistence level, or if employed off the farm, raises or home-processes at least some of the food consumed. Increasing the value of locally produced agricultural products provides a possible avenue for improving the standard of living of people around the world. Therefore trade in agricultural products would seem to hold much promise for improving livelihoods across the world, and this would be true if trade were free and fair. Unfortunately, the food regulatory framework in much of the developing world does not function effectively, due to rampant governmental corruption, lack of a legislative and regulatory framework, a lack of human and financial resources to implement a system, or a lack of political will to develop an effective system of food regulations and the enforcement policies that would accompany it. However, it is clear that the development of domestic production to substitute for imports is a critical need in much of the world if people are to have enough wholesome food, but this is difficult to expedite if the in-country food regulatory system is not reliable or trusted in the marketplace. In addition, tariffs are enacted and non-tariff trade barriers erected against the creation and growth of food export markets by the potential importing countries as a means of protecting their own markets resulting in major impediments to building export markets in developing countries that could generate jobs and economic development in agricultural communities.

There are numerous regulatory issues that affect the food system, some surrounding the use of additives, genetically modified foods, the application of treatment processes such as irradiation, and the use of agricultural chemicals. Having an unstable regulatory environment poses numerous problems not just for farmers trying to operate successfully in an increasingly globalized agricultural economy but also for companies in developing nations desiring to build export markets for food products. For example, the unregulated use of pesticide in India has made it difficult to create legitimate export markets and has led to the dumping of potentially dangerous products onto local markets where food safety and environmental monitoring of food safety are weak. In another case, activism from outsiders, particularly in Africa, has created political barriers to the introduction of new processing methods such as irradiation and to the introduction of genetically modified food crops where this could be highly beneficial. Some of this activity has been successful and has led to misguided but widely cited standards such as the bio-safety protocols promoted by the African Union for risk assessments involving the introduction of genetically modified plants.

An additional impediment to the growth of agricultural economies in the developing world is a lack of either clarity or flexibility in the technical specifications for agricultural products. In many developing countries this has made trade problematic. A lack of reliable product standards in domestic markets may remain, despite apparent resolution of product standards in the international arena. The rhetoric on international harmonization of market standards and adoption of these international standards at a national or local level is compelling but efforts along these lines have been less than effective when it comes to trade in food products. Reaching a consensus on international technical specifications is a slow process, with groups such as Codex Alimentarius tasked with the development of these. Lack of responsiveness within Codex to the development of realistic standards within a reasonable time frame has had a negative impact on the development of export markets for agricultural producers in developing countries. Because of a lack of internationally harmonized standards, costly programs have been created which protect developed markets in Europe and Japan creating hurdles for new market entrants.

One bright spot on the food regulatory front have been the major recent advances of the Baltic States of Estonia, Latvia and Lithuania of the former Soviet Union with their successful transition from the former Soviet set of governmental standards (GOST) to international market based standards for food and various industrial and consumer products. Countries of the Commonwealth of Independent States (CIS), former Soviet republics, are following their example, and are attempting to transition to international market standards despite problems with governmental corruption and lack of a suitable regulatory framework in a number of the affected countries. Unfortunately, groups which should be expediting this transition have stifled this attempt at a transition to a market economy in the CIS. The International Standards Organization (ISO), for example, charges high prices to simply obtain product technical specifications and then on top of this, has created an extremely expensive non-transparent certification and audit programs that makes it difficult for firms with limited resources to enter world markets where compliance with ISO standards has been specified. This impedes the transition to a market economy in developing nations where the greatest potential for job creation and wealth creation remains, at least for the time being, in the agricultural sector. Further, individual countries in Europe and Asia also erect trade barriers that lack transparency either as to the required product technical specifications, food safety standards, labeling and records requirements, or import requirements, taking these deliberate protectionist steps to foreclose foreign competition in their markets.

1.2. The Importance of Food

Food is an essential ingredient for human life. It serves as the source of energy and nutrients for the biological activities of the human body. Production, processing, distribution and sale of foods are an integral part of modern economics and the basic fabric of human society. Raw materials for foods are produced mainly by agricultural activities, although some products are gathered from nature (*e.g.* mushrooms and medicinal plants) or hunted (*e.g.* marine and freshwater fish and shellfish, wild game). All food products are perishable relative to other natural materials in commerce such as forest products and fuel. Food products require the use of preservation measures to

make them stable, safe for consumption, and extend shelf-life. Products such as fresh produce, muscle foods, and fluid milk have no more than 10 days shelf life even with the use of the best current technologies available. Almost all of our food products require the use of processing technologies to add value so that they can be held past the immediate harvest period. Many different processing methods are available to make food ingredients or products more convenient to use.

Technologies used for food preservation and value-added processes vary among different nations, and this is mostly determined by the level of industrialization and development of communities in each nation. In developed nations with large urban population centers, food processing operations are large-scale and complex. In developing nations where the majority of the population is in rural areas, growers may not have access to elaborate methods for creating value-added food products. In such cases, farming systems alone with the transport of raw product directly to a consumer may constitute the extent of the food distribution system.

Distribution networks are very important for expanding the customer base for a particular food product regardless of where food is produced and sold. In less developed nations these networks are limited, resulting in local distribution of a grower's goods. In heavily industrialized regions such as North America, Asia, and Europe, distribution companies provide a global network for product dispersion. In many instances distribution networks are becoming an integral part of the retail sector of the food system. Retail firms rely heavily on these distributors to provide products that draw consumers to their business and this often allows the retailer to create competitive pricing advantages.

In summary, many different factors impact the modern food system. Some of these are driven by market and government regulatory requirements, others by the degree of community development and environmental conditions in the local area. For the food processing industry, which is the primary focus of this chapter, a number of factors are in place to encourage the production and delivery of safe and wholesome food products in compliance with international sanitary, phyto-sanitary and product standards. The increasing trend towards globalization of food supplies should enhance the overall efficiency of food system worldwide and is one way of providing consumers with a greater variety of food from the lowest cost producer wherever that producer may be located. This emerging market structure also creates new challenges related to international trade, food safety, and food security.

The following sections provide an overview of the status of foods systems on a global scale, and an in-depth look at each segment of a food system.

2. Food System

The food system is a complex network of stakeholders that function cooperatively to feed the world's population. The system includes farming, raw material shipping and handling, processing, distribution, vending, consumption, and waste disposal. For the overall process to be effective and sustainable, the food system must yield products that are safe, accessible, nutritious, and with acceptable sensory characteristics. The food

system should be environmentally sustainable, and provide economic values to the regions which support it.

Figure 1 provides a simplified diagram for the flow of materials between different segments in a modern food system. The number of segments from the grower to the consumer varies widely with geographic location, economic status, and the type of food product supplied. For example, in many countries, grain may go through several processing operations, distributors, wholesalers, and retailers before reaching the consumer in the form of a final food product. But in some markets, the consumer may process the raw grain at home and then into a food item, as the case for millet in parts of Africa and maize in Central and South America for traditional food items.

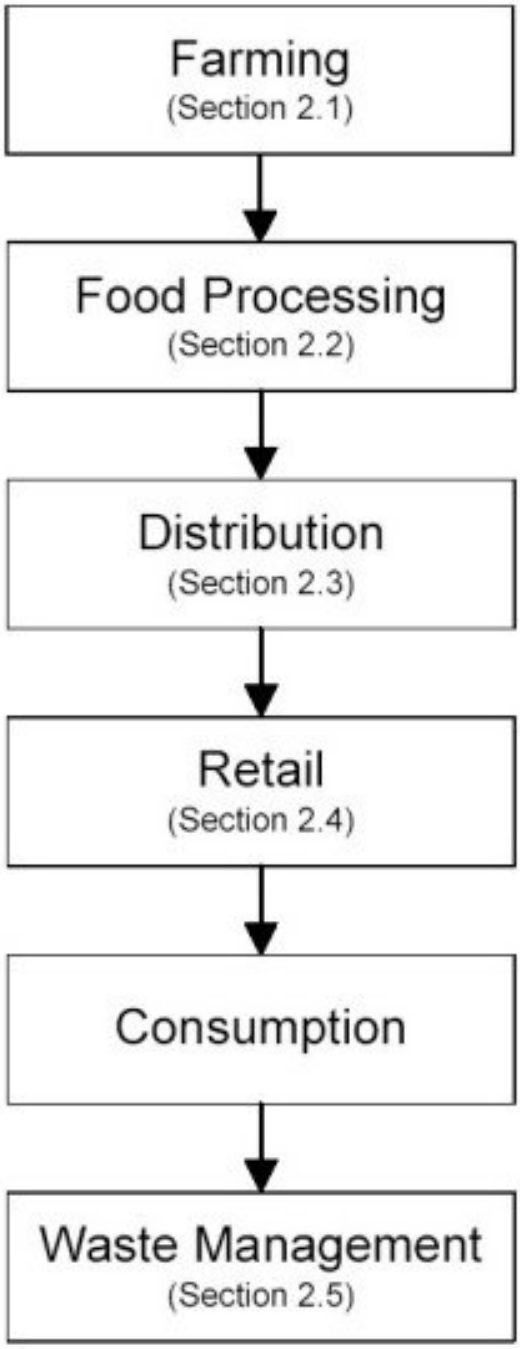

Figure 1: Food system

Each component within the food system may be thought of as an individual control system, with boundaries across which are flows of materials, energy, and information. Figure 2 shows the flow of energy that includes the chemical energy stored in foods to support human activities as well as the electric, chemical, and mechanical energy used in its transportation and processing.

Figure 2: Demonstration of energy flow through a control system

Effective flow of information, including scientific and economic information, among different market sectors is vital for the sustainable operation of a food system. The internet, telephones, radios, televisions, and printed media form a communication network between the key players involved in any given food system. Figure 3 illustrates a simplified diagram for the flow of information among major elements within a modern food system. Information flow may cut across several sectors and can be much more complicated than depicted in this diagram.

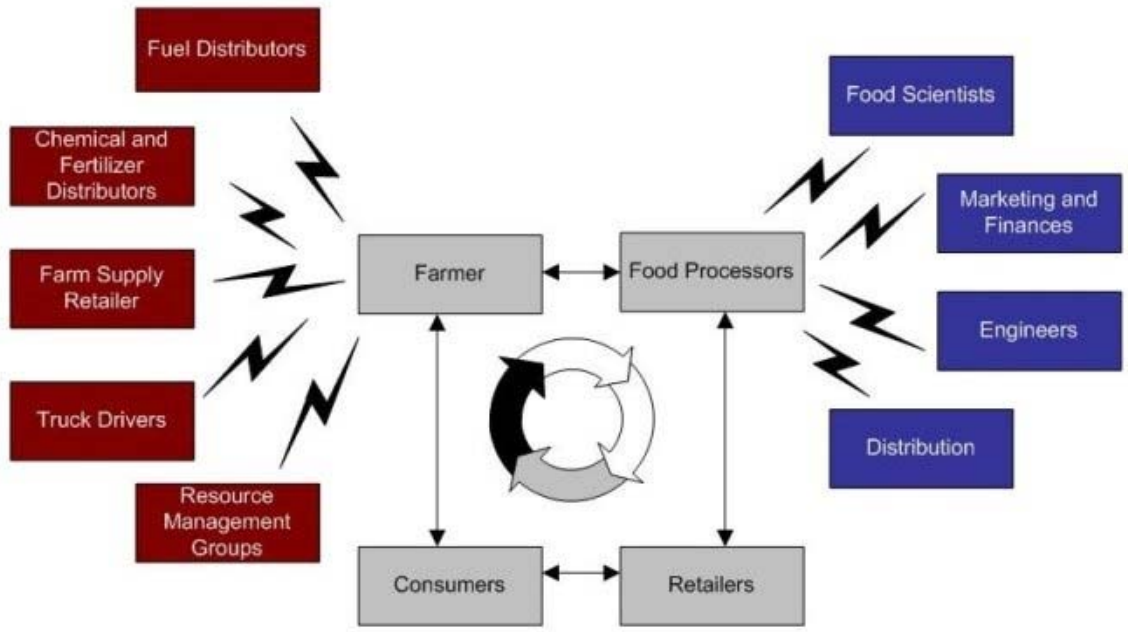

Figure 3: Overview of communicative networking

A connection often exists between producers and consumers. Bazaars in many parts of the world are still the major retail food markets and even in developed countries, consumers commonly purchase fresh produce from local farmer's markets. Otherwise feedback to farmers from consumers is less direct. The extent to which a producer communicates with a retailer or consumer depends upon geographic and economic factors as well as the nature of the products being sold. Fresh produce sold in retail

markets often involve fewer steps in the supply chain from the producer to the consumers compared to processed products such as thermally processed foods, frozen foods, bakery or snack foods. However, certain categories of those produce are the most highly engineered foods currently sold in the marketplace. For example, very sophisticated controlled atmosphere packaging and storage facilities are used for these foods; many horticultural and genetic controls and agricultural production protocols (like GAP) are in place to ensure that products have the desired quality (*e.g.* size, color, transportability, progression through senescence). The cost to transport these foods to market, particularly to distant markets, is high and involves refrigeration, hydro-cooling and various types of controlled atmosphere (CA) packaging. Other sophisticated technologies, including control of ripening protocols (*e.g.* ethylene treatment for bananas) and application of edible films and coatings to control moisture loss, control respiration and potentially microbial growth, provide physical protection and maintain an acceptable appearance for the product. The use of air freight to serve export markets is common even for products being shipped from the developing world. Globalization of agricultural produce provides opportunities for improving family income and enhancing agricultural economic development in areas of many countries where the economy is depressed but where the climate will support the growth of specialty products such as fresh fruits and vegetables, herbs and botanicals.

In many countries, university and governmental agencies play an important role in the food systems by providing scientific, technical and market information to players in the agricultural system. University research and extension in the USA, for example, provide technical assistance to farmers and small food processors in production and processing activities. Local grower's associations, such as the Washington Tree Fruit Commission, provide marketing data and assistance as well as grants to universities to improve cultivars, agricultural practices and develop new products and markets. In this particular case, funds for the Commission are raised through an assessment based upon a predetermined percentage of the value of commodity product sales. In some cases, state departments of agriculture also provide technical and market assistance to growers. Federal agencies in the USA, such as the Agricultural Marketing Service and Foreign Agricultural Service, assist farmers and food producers with market development efforts. Other agencies set standards for product labeling (the Food and Drug Administration (FDA), the US Department of Agriculture (USDA)) and product safety (FDA, USDA, and the Environmental Protection Agency (EPA)) that promote consumer confidence in the marketplace regarding product safety, wholesomeness and quality, market grades and composition.

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Biographical sketches

Catherine Cantley is currently working on her MS in agricultural and food process engineering at Purdue University. Her work focuses on enhancing the detection sensitivity of a field-use device used to detect *Listeria monocytogenes* in food processing environments. She completed her BS in biological systems engineering at Washington State University. There she worked on the development of radio frequency and microwave systems used for the sterilization of food products.

Juming Tang, PhD, is a professor of food engineering in the Department of Biological Systems Engineering at Washington State University, Pullman, Washington. He teaches and conducts research in food processing engineering, thermal processing, and novel food preservation technologies. Dr. Tang has published over 120 peer reviewed scientific papers, over 10 book chapters and two books in the above areas. Dr. Tang is a Washington State University IMPACT Center Fellow and directs multi-disciplinary research programs related to non-chemical pest post harvest control of agricultural commodities in international trades and development of novel food processing technologies based on microwave and radio frequency energies.

Barbara Rasco, BSE, PhD, JD is a Professor with the College of Agricultural, Human and Natural Resources Sciences at Washington State University and a Fellow with the Institute of Food Technologists. Her research involves food safety and defense including the development of new analytical methods and processes for aquatic foods and other products. She has over 150 publications in these areas. Dr. Rasco has participated in economic development projects in 26 countries over the past 10 years to improve the market value for food and food security within communities. Much of this work involves evaluations of domestic and export market potential for agricultural crops and processed foods in countries with emerging economies along with improvements to food production practices so that these meet international market standards. In addition, Dr. Rasco assists with the development of legislative initiatives, government policy, and regulatory reform in the agricultural sector.

Dr. Lester A. Wilson is a 'University Professor' of Food Science and Human Nutrition, a team member of the Center for Crops Utilization Research, and an affiliate faculty member of the Institute for Food Safety and Security at Iowa State University. He was selected as a NASA Faculty Fellow in 2003, 2004, 2005, and 2006. Professor Wilson was given the title of "University Professor" for 'outstanding university citizenship and service to Iowa State University and to the public that it serves' in 2006.

He has been recognized for his commitment to quality teaching, advising, and his participation in technology transfer/outreach programs helping farmers and food processors with soy, apple cider, fruits, vegetable products, and food safety programs over the last 32 years.. Dr. Wilson's research centers around the influence of processing, food chemistry, and their influence on food quality, safety, and consumer acceptance. He is nationally and internationally recognized for his work on tofu processing and quality.