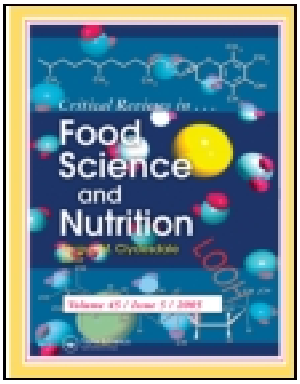

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Global Hunger: A Challenge to Agricultural, Food, and Nutritional Sciences

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Global Hunger: A Challenge to Agricultural, Food, and Nutritional Sciences

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Hunger has been a concern for generations and has continued to plague hundreds of millions of people around the world. Although many efforts have been devoted to reduce hunger, challenges such as growing competitions for natural resources, emerging climate changes and natural disasters, poverty, illiteracy, and diseases are posing threats to food security and intensifying the hunger crisis. Concerted efforts of scientists to improve agricultural and food productivity, technology, nutrition, and education are imperative to facilitate appropriate strategies for defeating hunger and malnutrition. This paper provides some aspects of world hunger issues and summarizes the efforts and measures aimed to alleviate food problems from the food and nutritional sciences perspectives. The prospects and constraints of some implemented strategies for alleviating hunger and achieving sustainable food security are also discussed. This comprehensive information source could provide insights into the development of a complementary framework for dealing with the global hunger issue.

Keywords Hunger, food security, malnutrition, food sustainability, food science, nutrition

INTRODUCTION

Since the adoption of the United Nations Millennium Declaration in 2001 to improve human well-being by alleviating hunger, poverty, and disease, many efforts have been devoted to achieve one of the targets of the Millennium Development Goals (MDGs)—to reduce the prevalence of hunger by half between 1990 and 2015. Many studies have revealed the possible directions for scientists to boost food production to meet the food demand of world population. It should be noted that although the world's population is still increasing, the pace of increase is in fact getting slower and will even start to decrease in the next few decades. The population (medium variant) in more developed regions and eastern Asian countries would decline after the years 2035–2045 (UN, 2009; FAO, 2010). Nevertheless, numerous people around the world are still suffering from hunger and lack of basic food intake necessary for survival and productive lives. It is imperative to raise greater awareness for scientists to adopt the appropriate strategies for defeating hunger. In this review, we attempt to take a critical but practical look at the prospects and constraints of some implemented strategies designed for alleviating hunger from the food and nutritional sciences. Within this paper, we will also address some issues of technological advances on the priority agenda aimed to achieve global food security.

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TRENDS OF GLOBAL HUNGER

Since 60s, an intensification practice in agriculture has contributed to increasing the global agricultural supply (~2.3% per year from 1961 to 2005) (FAO, 2007; Lal, 2009). However, after nearly 40 years, hunger and malnutrition issues are still great challenges to the world and among the major causes of human death, killing nearly six million children each year (FAO, 2005a). It is estimated that a total of 925 million people are undernourished in 2010 than 1.023 billion in 2009 (FAO, 2010). At close to one billion, the number of hungry people in the world still remains unacceptably high. Most of them are located in developing countries, especially in Asia and the Pacific and sub-Saharan Africa (SSA) (FAO, 2009a , 2010). Though the underlying causes of hunger vary greatly among countries, the causes of child hunger and undernutrition are in fact predictable and preventable, and can be addressed through affordable means (von Grebmer et al., 2010). Factors such as natural disasters, political and economic instability, inflation, high food prices, and production shortfall commonly cause transitory food insecurity in the short-term. On the other hand, factors such as world population, climate changes, diminishing natural resources (e.g., land, water, energy, biological resources), infectious diseases (e.g., HIV/AIDS pandemic), low levels of education and literacy, and inadequate application and distribution of technology also cause substantial impacts on global food security and create obstacles for the reduction of hunger in the long run (WFP, 2009; Nah and Chau, 2010).

Developing countries account for 98% of the world's undernourished people. Figure 1 presents the countries with a high number of undernourished people (more than 30 million) and/or high proportion of undernourished people in total population (over 30%). Although the numbers of undernourished people in many countries are less than 10 million, they may indeed have a high proportion of undernourished people in total population. The number of undernourished people remained high (up to two-thirds of the world's undernourished people) in countries such as India, China, Bangladesh, Indonesia, Pakistan, the Democratic Republic of the Congo, and Ethiopia. Over 40% of the world's undernourished people live in China and India alone. However, the Democratic Republic of the Congo and Ethiopia held a very high proportion of undernourished people in total population (i.e., 75% and 66%, respectively).

The prevalence of hunger declined from 20% of the world population undernourished in 1990–1992 to 16% in 2010, indicating a progress toward the achievement of MDG1 (eradicating

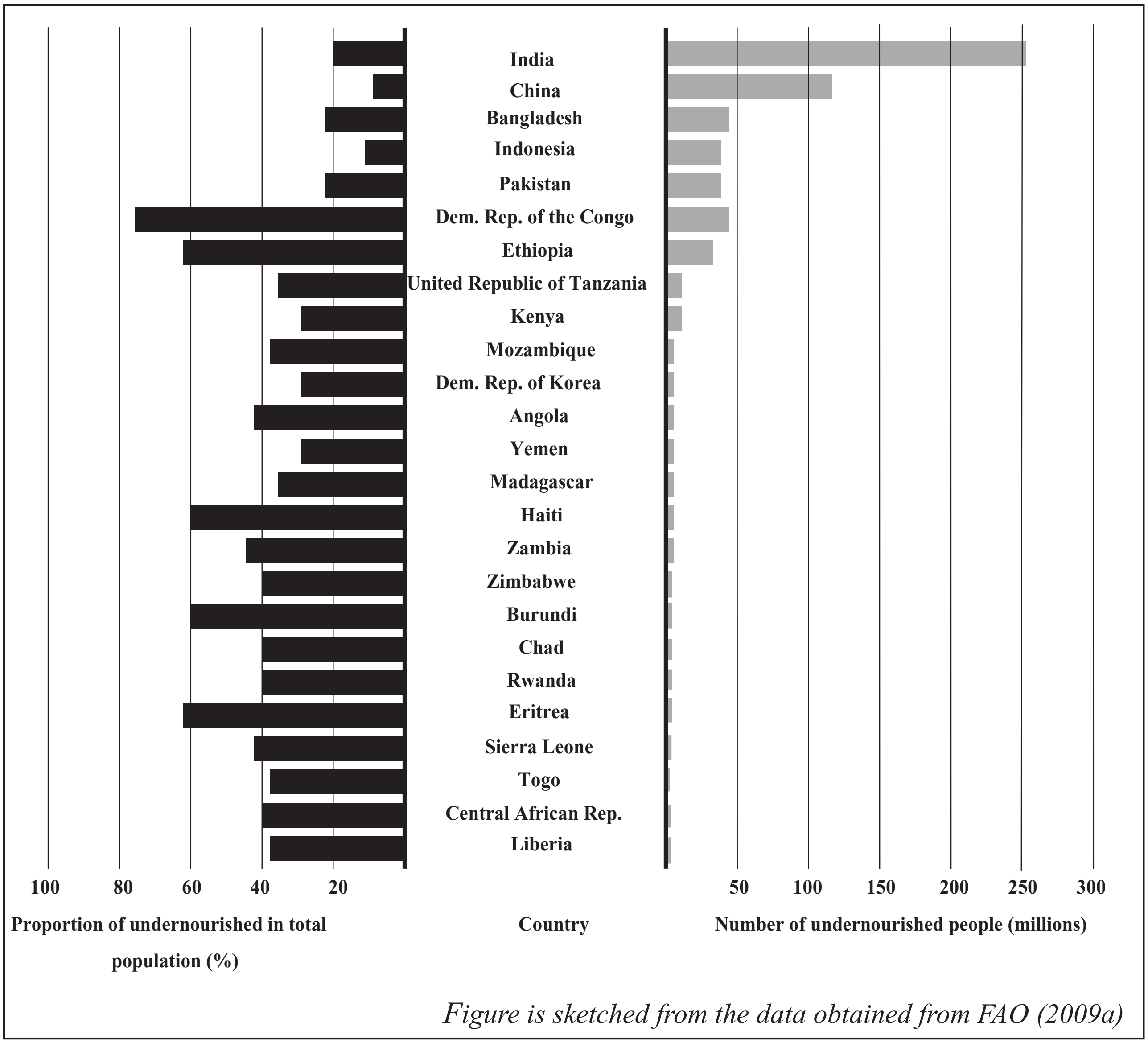

Figure 1 Prevalence of undernourishment in countries with a high number of undernourished people (more than 30 million) and/or a high proportion of undernourished people in total population (over 30%).

hunger and extreme poverty in half by 2015). The number of hungry people in the developing countries as a group was however elevated from 827 million in 1990–2002 to 906 million in 2010 (FAO, 2010). The reduced proportion of undernourished people could possibly mask the actual increase in the number of hungry people. Despite the recent decline in global hunger (but still unacceptably high), international hunger targets such as MDG1 are yet difficult to reach (FAO, 2010; von Grebmer et al., 2010). Continuous global efforts as well as commensurate strategies should be pursued on multiple fronts including scientific, environmental, technological, socioeconomical, and political aspects for a sustainable and equitable food security. From the food and nutritional sciences aspects, concerted efforts of scientists to improve food productivity, nutritional quality, technology, availability, accessibility, distribution, education, and food safety management are imperative to facilitate the adoption of appropriate strategies for defeating hunger and malnutrition (Nah and Chau, 2010).

FOOD PRODUCTION SYSTEM

A food production system encompasses the entire food production chain from farm to table. Improving agricultural productivity as well as managing all different stages of the system (e.g., on-farm, postharvest processing, distribution) on a sustainable basis are crucial to produce adequate food supply while maintaining the integrity of ecosystem.

Agricultural Productivity

Oftentimes, increasing food production is a path out of poverty for many poor families, indeed usually the only route available. Improving agricultural productivity through the applications of science and technology has always been one of the interventions adopted to increase food supply for the world's population. For example, an increase of total factor productivity in China's agriculture by almost 50% from 1988 to 1996 was primarily driven by technology adoption (Khan et al., 2009). During 1980 to 1995, the technology adoption has also accounted for an estimated 40% of the increase in rice productivity of China (Jin et al., 2002). An elevation in agricultural productivity may have immediate impacts on food security and reduce global poverty through increasing farmers' incomes and decreasing food prices (Diao et al., 2008).

From the seed-based approach, a considerable amount of studies have been conducted using molecular genetic technology to develop different crop varieties with improved characteristics including disease- and pest-resistances, shorter breeding cycle, better water conservation, and drought-tolerance (Sharma et al., 2002). Transgenic crops such as ringspot virus-resistant papaya, blight resistant-potato, and leaf blight-resistant rice have proved the effectiveness of genetic modification (GM) in controlling pests (Sharma et al., 2001). This biotechnology has benefited poor farmers in some countries to produce a higher crop yield. In 2009, 14 million farmers in 25 countries grew genetic-modified crops commercially; over 90% of them were small and resource-poor farmers in developing countries (James, 2009). Applications of GM technology in the developing countries have markedly increased the average crop yield from 16% (for insect-resistant corn) to 30% (for insect-resistant cotton) (Carpenter, 2010).

Furthermore, some researchers have focused on increasing crop productivity through physiological responses of plant crops under optimum conditions. For the most productive crops (e.g., sugarcane), under optimum growing conditions, they can convert solar energy with an efficiency of ∼2% into 150 tons of biomass per hectare (Gilbert et al., 2006). This physiological approach offers an opportunity to potentially increase crop yields without further extensification of food production at the farm level.

Postharvest Processing

Appropriate off-farm operations involving postharvest processing, marketing, and storage are of vital importance, where up to 40–50% of the postharvest losses may occur (Kader, 1992; Fresco, 2009). The importance of postharvest processing lies in its potential to meet food demand of the world population by eliminating avoidable losses through proper processing and consequently ensure better returns to the farmers. Development of affordable postharvest technologies for food selection, preservation, processing, packaging, transportation, and storage could prevent postharvest losses and improve food availability, especially in the food-insecure countries. For example, the investments of affordable technologies (e.g., small metallic silos) in China markedly reduced their rice postharvest losses by 8−26% (Ren-Yong et al., 1990). Different conventional postharvest processing methods such as drying, heat processing, fermentation, and curing have long been used to improve food edibility and nutrition, eliminate detrimental substance, extend shelf life, and enhance organoleptic quality of agricultural food products (Svanberg and Lorri, 1997; Holzapfel, 2002; Sharma et al., 2009; Tiwari et al., 2009). The fact that higher postharvest losses being observed in developing countries (up to 50%) than those in developed countries (5–25%) are probably due to the lack of adequate physical infrastructure (e.g., transportation, refrigeration, storage facilities) and properly functioning markets in those developing countries (Kader, 1992). The lack of knowledge and skills in production–planning and postharvest handling in the poor developing countries are the other contributing factors toward their low food production rate and high postharvest losses (Dannson et al., 2004).

Moreover, postharvest technologies also have the potential to bolster rural industries. Depending on each country's specific situation, the processing techniques for different perishable staple foods could range from "simple" within traditional societies to "novel scientific" using sophisticated modern concepts (Nah and Chau, 2010). While simple and low-cost traditional food preservation (or processing) techniques are the bedrock for people in food-insecure and poor countries to extend the availability of their perishable staple and food crops, innovative processing methods such as pulsed electric fields (Gerlach et al., 2008), high-pressure treatments (Wilson et al., 2008), and irradiation (Farkas, 2006) have been developed to add values (i.e., convenience, extended shelf life, improved nutrition and quality) to the agricultural products prior to marketing. Proper applications of these postharvest technologies could increase global food availability by facilitating multilateral trade and transportation of food.

Food Distribution

Provided that the food production at 1990 levels was equally distributed to the world population, every individual on the earth could share more than 2700 calories per day (Buckingham, 2003). However, in the modern society, many food-insecure countries are suffering from chronic hunger due to their production failures at the local level, whereas some developed countries continue to produce a surplus of food. This may be partially attributed to the fact that most of the foods produced are mainly for local consumption while only a small proportion (∼10%) is traded internationally (3D, 2005; Tubiello et al., 2007). The disparity in food availability is expected to be widened as the moderate increase in temperature forecasted for the first half of this century might increase the average yield in the temperate and high latitude regions but reduce crop yield in the semiarid and tropical regions with declining precipitation (Tubiello et al., 2007; Lobell et al., 2008). In point of fact, global food supply is very unequally distributed.

Effective trade and distribution systems are indeed important factors in the world food security equation to ensure wider food access at the national and international levels. In Asian countries, effective food distribution and trade activities have significantly increased their share of grain consumption since 70s, particularly in East and Southeast Asia. East Asia's net annual cereal imports were equivalent to 10% of East Asian consumption in 1990 (Peng et al., 2002). At present, the developed countries are net cereal exporters while the developing countries have increasingly become the net cereal importers over time. Efficient resources mobilization for a balanced distribution of food is essential to ensure the right to food worldwide. Substantial improvements to the major components of food distribution (e.g., transport infrastructure, food handling technology, and adequate source and supply logistics) hence should be made to enhance the efficiency in the food insecure countries. Furthermore, the right to food is also determined by the ability of individuals and groups to gain access to adequate (i.e., sufficient, safe, and nutritious) food, both economically and physically (FAO, 2008a). Since economic performance and hunger are inversely correlated, the issue of poverty might remain an economic challenge for undernourished people to obtain adequate foods even when sufficient food technically exists.

HUNGER AND MALNUTRITION

Hunger and malnutrition as the common issues of humankind are the number one challenge to the health worldwide (http://www.wfp.org/hunger). Although these terms are closely related, they actually have different meanings. Hunger is a condition in which people lack the macronutrients (energy and protein) and micronutrients (vitamins and minerals) for fully productive, active, and healthy lives (WFP, 2007, 2009). It can result from insufficient nutrients intake or from impaired absorption (malabsorption) of the required nutrients by human body (also called hidden hunger) (WFP, 2009). Malnutrition is a physical condition in which people experience either a deficiencies of nutrients (undernutrition) or an excess of certain nutrients (overnutrition) (WFP, 2009). Undernutrition, as the physical manifestation of hunger, can be relieved by providing appropriate amount of micronutrients (vitamins and minerals) to meet the daily nutritional requirements (http://www.wfp.org/hunger/malnutrition/types). The devastating effects of undernutrition are more pronounced in the countries with a large number of hungry people (Table 1). On the other hand, overnutrition (e.g., obesity) is generally relieved by calorie reduction or restriction (Behrman et al., 2004).

As discussed above, worldwide disparities in food accessibility are widening. In the world today, about 1.02 billion people are undernourished when in fact over 1 billion of adults are overweight (WHO, 2003 , 2005; FAO, 2009a). The dietary patterns of wealthy people in general tend to be high in complex carbohydrates with a high proportion of fats and sugars (WHO, 2003). Such dietary patterns increase the number of overweight people and it is even projected that over 1.5 billion people will be overweight by 2015 (WHO, 2005). Since the diverse, nutritionally well-balanced diets are unaffordable to the residents living in low-income, food-deficit countries, most of these people depend entirely on staple crops (e.g., sorghum, millet, cassava, banana, yam, other starchy crops) to survive (FAO, 2008b). The dependency on high-starch crops as the sole food sources to meet caloric requirements may lead to inadequate nutrients intake and cause malnutrition eventually.

In addition, the spread of HIV has increased the complexity of reducing hunger and undernutrition. The burden of HIV is significant in SSA (i.e., 22 million people living with HIV) (WFP, 2007; WHO, 2009). The HIV epidemic is both a cause and effect of hunger and undernutrition. HIV infection reduces the intake, absorption, and utilization of micronutrients, and contributes to micronutrient deficiencies; meanwhile, hunger increases the risk of HIV transmission, compromises antiretroviral therapy, and hastens the onset of acquired immune deficiency syndrome (AIDS) (WFP, 2007). Micronutrient deficiencies will impair immune function and is likely to increase the rate of infection and progression (Villamor et al., 2004; Fawzi et al., 2005; Kupka et al., 2005). As the consequence, HIV would drain the household incomes for medical treatment, reduce the capability to buy food, and increase poverty. At the national level, the epidemic is likely to contribute to the loss of agricultural

Table 1 Example of nutrient deficiencies and their devastating effects to food security

Nutrient deficiency	Threats to food security
Protein and calories	• Problems of protein-energy malnutrition or undernutrition—the main manifestations of malnutrition in developing countries • Determined based on the prevalence of underweight, stunting, and wasting (Müller and Krawinkel, 2005); nearly 26%, 30%, and 11% of children under the age of five years in developing countries being underweight, stunt, and waste, respectively (UNICEF, 2009) • Leading to marasmus (caloric deprivation) and kwashiorkor (severe protein malnutrition) (Castiglia, 1996)
Fat	• Low quantities of total fat being consumed in poor countries, especially Africa • About 19 countries falling below the minimum recommendation of 15% dietary energy supply from fat, particularly in SSA and South Asia (WHO/FAO, 2003)
Vitamin A	• 100−140 million children suffering from vitamin A deficiency, with an estimated 0.25 to 0.5 million being permanently blinded (Shetty, 2006)
Iodine	• Nearly two billion people worldwide suffering from inadequate iodine nutrition (http://www.wfp.org/hunger/stats) • 31.5% of school-age children worldwide (equivalent to 266 million) having insufficient iodine intake (de Benoist et al., 2008) • Approximately 20 million children with mental handicap as a result of iodine deficiency; including 100,000 children born each year with irreversible brain damage due to their mothers lacking iodine before and during pregnancy (Shetty, 2006)
Iron	• 50% of the cases of anemia generally attributed to iron deficiency (WHO, 2001) • Approximately 1.62 billion people worldwide having anemia (24.8% world population) (WHO, 2008) • More than 40% of preschool-age children having moderate or severe anemia (hemoglobin levels below 10 g/dL), especially in Africa and Asia (Population Reference Bureau, 2007)
Zinc	• An estimated 5.5% of child deaths worldwide resulting from zinc deficiency, a major determinant for diarrhoeal disease, pneumonia and malaria, low birth weight, and stunted child growth (Sanghvi et al., 2007; WFP, 2007) • Causing nearly 176,000 diarrhea deaths, 406,000 pneumonia deaths, and 207,000 malaria deaths (Caulfield and Black, 2004)

production as the availability of skilled labor and essential agriculture knowledge decrease due to an increase of HIV victims (Rosegrant and Cline, 2003). From 1985 to 2000, HIV has killed around seven million agricultural workers in the 25 hardest-hit SSA countries and 16 million more are likely to die before 2020 (http://www.fao-ilo.org/more/hiv/en). Some other constraints such as low levels of education and literacy, social status, limited facilities, unaffordable technologies, and poor sanitation are likewise undermining the productive capacity and increasing the numbers of hungry and undernourished people (FAO, 2005b; Nah and Chau, 2010). To feed the world, the world needs more science as well as more commercial agriculture (i.e., high-productivity large farms). There is clearly a need for constant research and technology development to help the people who cannot obtain even the most basic amount of food and nutrition needed for survival.

TECHNOLOGICAL ADVANCEMENT AS A POSSIBLE SOLUTION

The food system encompasses a range of social, institutional, and ecological components, and thus the complexity of food insecurity within this system should be tackled from multiple perspectives (Ericksen, 2008). An integration of multidisciplinary research (e.g., food science, agronomy, genetic, molecular biology, chemistry, physiology, engineering, economy) provides knowledge to furnish commensurate elucidations from different disciplines to collectively eradicate hunger. In recent years, the problem of food security has initiated more scientific disciplines like agroecology, agrometeorology, and pedology that work together to help find solutions. The contribution of science and technology should always be a part of the integrated strategy to cope with the emerging food security issues and challenges. Some organizations and institutes such as Food and Agriculture Organization of the United Nations (FAO) (http://www.fao.org), International Food Policy Research Institute (IFPRI) (http://www.ifpri.org), Consultative Group on International Agricultural Research (CGIAR) (http://www.cgiar.org), International Fund for Agricultural Development (IFAD) (http://www.ifad.org), and International Union of Food Science and Technology (IUFoST) (http://www.iufost.org) have undertaken the initiative to conduct collaborative research to increase agricultural production, conserve natural resources, promote yield-enhancing technologies, and facilitate adaptation to global changes, in response to the current global hunger and poverty concerns.

In order to achieve the common goal, it is crucial for scientists to develop affordable and acceptable technologies and disseminate research findings to ensure the accessibility of the potential technologies for the poor and food-insecure people. For example, the acceptance and utilization of technology has been useful to boost farm productivity and raise rural income in Asia (Paarlberg, 2008). Scientific and technological advancements have accelerated the shift from traditional to modern food production systems in satisfying the essential demand of food. Some of the major developments in food science and nutrition throughout the decades of century are illustrated in Figure 2. In short, it is highly possible that technological advances can reduce production costs and make it possible, at given prices, to produce food at a rate that outstrips both the population growth and food demand (Wik et al., 2008).

Technology Applications to Alleviate Hunger and Malnutrition

Various processing technologies such as drying and heat processing, fermentation, refrigeration, modified atmosphere,

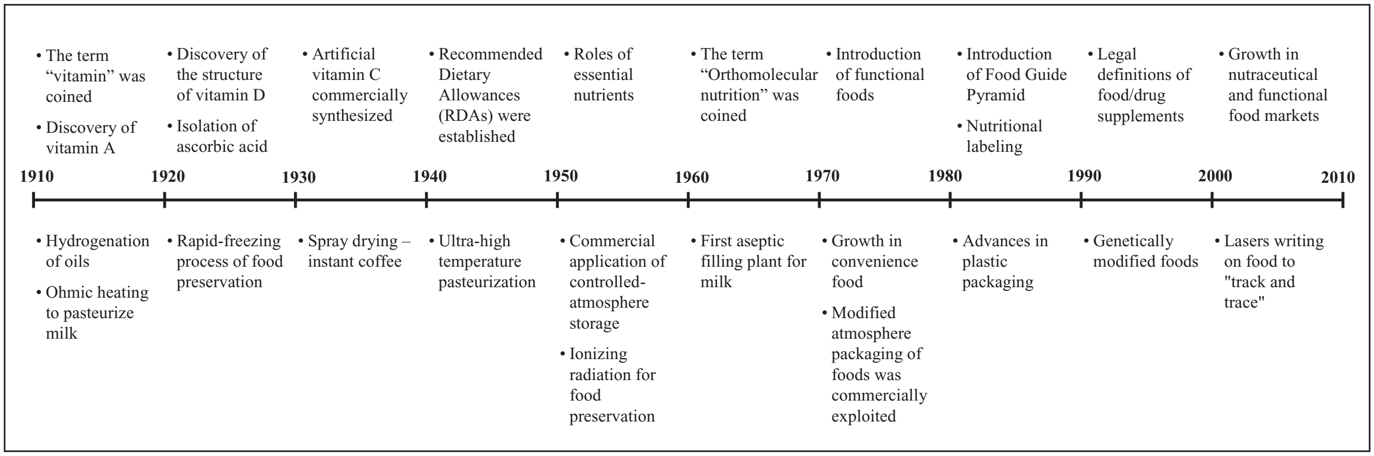

Figure 2 A summary of some developments in food science and nutrition throughout the decades of the century (1910−2010).

germination, milling, and soaking have been applied to reduce the postharvest losses of perishable staples and food crops as well as to enhance the nutritional quality, storage, transportation, and preservation of food (Svanberg and Lorri, 1997; Holzapfel, 2002; Bimbenet et al., 2007; Sharma et al., 2009; Tiwari et al., 2009). Appropriate processing is indeed necessary to eliminate toxicity, enhance organoleptic acceptability, inactivate antinutritional factors, and increase the utilization and nutrient bioavailability of different food crops (e.g., maize, millet, yam, bean, cassava) (Wilkinson, 2004; Bhandari and Kawabata, 2006; Nah and Chau, 2010). For instances, treatments (e.g., molecular techniques, heat treatment, wetting method) on cassava to reduce cyanide poisoning and improve its edibility and safety were one of the examples to demonstrate the importance of food processing on enhancing the utilization and safety of staple food in Africa (Cardoso et al., 2005; Bradbury et al., 2011; Nambisan, 2011). Other innovative processing technologies such as pulsed electric field (Gerlach et al., 2008), solar-drying technology (Sharma et al., 2009), high-pressure treatment (Wilson et al., 2008), irradiation (Farkas, 2006), biofortification (Zhao and McGrath, 2009), and biotechnology (Sharma et al., 2002; Eicher et al., 2006) have presented highly promising alternatives to improve the nutritive value, characteristics, utilization, and shelf life of crop and food products. The development of Golden Rice rich in β-carotene (Ye et al., 2000) and transgenic potato with improved essential amino acids balance (Chakraborty et al., 2000) are well-known examples of the potential of biotechnology to increase the nutrient bioavailability of crops. Moreover, research efforts have also been devoted to develop drought-tolerance crop plants (Pennisi, 2008) as well as to improve water productivity and water resources management (Ali and Talukder, 2008; Lal, 2009; WWAP, 2009) to withstand harsh agricultural environment. These technologies may stimulate interest in the possibilities for the injection of more advanced scientific concepts and appropriate technologies into the current systems, with the goals of assuring sustainable crop yield and production.

Food aid dedicated to saving lives in emergencies has always required a constant technological research and development to ensure and improve efficiency in delivering immediate food assistance to hungry people. Some major organizations such as United States Agency for International Development (USAID) (http://www.usaid.gov), World Food Programme (WFP) (http://www.wfp.org), CARE International (http://www.care.org), Action Against Hunger (http://www.aah-usa.org), and Children's Hunger Relief Fund (http://www.chrf.org) have devoted their efforts to defeat hunger by providing food aid to the hungry people, especially in SSA. Inevitably, applications of appropriate technologies are required to establish the production of safe and nutritious food for humanitarian aid. Some common approaches such as micronutrient supplementation and fortification of general food products (e.g., biscuits, cereals, sugar, wheat flour, maize meal, rice) are usually performed in a number of countries suffering from malnutrition (WFP, 2007; FAO, 2008b). Advancements in food processing technologies (e.g., hot extrusion, cold extrusion, coating and dusting) and equipments (e.g., containerized food production unit, automatic dosing system) have enabled the development of different food aid products (e.g., fortified foods, fortified blended flours, ready-to-use supplementary foods, ready-to-eat meals, especially formulated foods) with considerations of local habits, staple food sources, nutritive values, taste, shelf-life, convenience, and safety (Bounie et al., 2010).

Social Consciousness of Advanced Technology

There are actually a number of interwoven and conflicting issues in the application of technology that may require greater oversight. In developing countries, the lack of scientific knowledge about the risks and benefits of different technologies (e.g., irradiation, genetically modification) may affect the acceptance and utilization of technologies (Lashgarara et al., 2008). The European ban and the consequential African ban on GM crops are indeed a political challenge to increase agricultural productivity growth and return the world to cheap food (Collier, 2008). In 2002, the governments of some African countries (i.e., Zambia) have rejected GM food aid (e.g., GM maize) from the United States even when the countries were facing drought and crop failure (Eicher et al., 2006; Paarlberg, 2008). The polarizing debate between agriculturalists and environmentalists on the suitability, utility, and risk of GM crops or foods typically results in confusion and paralysis of the agricultural biotechnology, discouraging African governments from approving the technology for commercial use. Due to the lack of access to scientifically improved farming technologies, smallholder farmers in Africa still remain starving for science and tend to fall behind in agricultural productivity and rural economic development (Paarlberg, 2008).

It should be noted that a violation of ethical principles in the application of technology in food production (e.g., adulteration or contamination) could have significant negative consequences on food supply and safety. In the past decades, repeated incidences of food safety problems such as counterfeit milk formula, use of prohibited drugs and chemicals in fishery, and the melamine contamination event (Chan and Lai, 2009) have devastated the food security situation. In the context of food producers, the misuse and misapplication of technological advancement in food production could jeopardize population health and safety as well as food security worldwide. At any time, ethical issues in the application of new and emerging technologies should not be disregarded.

EDUCATION AND KNOWLEDGE: ONE POTENTIAL SOLUTION

Education and knowledge have important impact on all dimensions of food security (i.e., availability, accessibility, utilization, stability). Possession of sufficient knowledge, skill and technical training enables the adoption of more advanced technologies for higher agricultural yields, increases employment opportunities and household earnings, improves nutritional practices toward better utilization of food sources, increases overall agricultural productivity, and also avoids over extensification of natural resources and environment (van de Walle, 2000; WFP, 2007; Bhutta et al., 2008). For example, in Vietnam, an additional year of formal schooling for the household head has raised the relative probability of escaping poverty by ∼11% (Glewwe et al., 2000), while an extra year of primary education has increased the average crop income by ∼8% (van de Walle, 2000). Educational gap, therefore, needs to be addressed without delay. Designing and reinforcing educational programs can indeed help the hungry people manage their financial resources, improve their skills, acquire safe and affordable foods, attain science-based knowledge, and maintain healthier lifestyles.

Knowledge and Skill—Building Blocks of Local Communities

The acquisition of knowledge and skills is the key to achieve better utilization of food sources (WFP, 2007), technology applications (IAASTD, 2009), productivity (WFP, 2009), agricultural yield (Clover, 2003), nutritional practices (Bhutta et al., 2008), maternal care (Bhutta et al., 2008; WHO, 2009), food safety (van de Venter, 2000), economic security (WFP, 2009), and employment opportunities (Koning et al., 2008). However, people in food-insecure countries are often hampered by a lack of knowledge and skills. In South Asia, relatively low levels of education and society status of women have adversely constrained the accessibilities of local children to balanced nutrients, resulting in a high child malnutrition rate (World Bank, 2006; WFP, 2007). In Africa, the agricultural production, which tends to be labor intensive and relies mainly on unskilled labor with low productivity, represents only 57 and 58% of those of Latin America and Asia, respectively (Economic Commission for Africa, 2009). The problem of unskilled labor directly impaired the agricultural productivity in food insecure countries (with undernourished population >34%) since over 70% of the country's labor force could only create 30% of their gross domestic product (Pinstrup-Aderesen, 2002).

Some organizations such as FAO (http://www.fao.org/ag/ags/en), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) (http//www.gtz.de/post_harvest), International Cooperation and Development Fund (ICDF) (http://www.icdf.org.tw), and Overseas Cooperative Development Council (OCDC) (http://www.ocdc.coop/OCDC/home5.html) have launched different international programs to provide locally appropriate training, agricultural knowledge, food processing techniques, and preservation techniques in the poor developing countries for productivity enhancement. Such offers of training in advanced technology and skill could create new employment opportunities and income-generating opportunities for poor people (Nah and Chau, 2010). The adoption of technology during the "Green Revolution" has provided employment for millions of people and helped relieve the problems of poverty as well as undernourishment in East Asia (Koning et al., 2008). However, knowledge and skills should be offered in parallel with technology adoption. In some of the low-income provinces or regions of China (e.g., Shanxi, Inner Mongolia, Anhui, Henan, Gansu, Qinghai, Ningxia), even though their machinery–labor ratio have increased, their agricultural efficiencies deteriorated by at least 2.6% simply due to the adoption of new but unfamiliar technologies (Chen et al., 2008).

Indigenous Knowledge as an Instrument for Food Sustainability

Indigenous knowledge (IK) and practices include the accumulated knowledge, skills, and technology, derived from the

Table 2 Different applications of indigenous knowledge and practices in relation to food production systems

Category	Different applications of indigenous knowledge and practices
Food sources	• Plantation of some traditional vegetables (such as *Solanum nigrum* and *Amaranthus*), known to be more resistant to diseases, nutrient deficiency, and water stress than exotic vegetables (Oniang'o et al., 2004) • Consumption of insects as important sources of protein and fat in the local diets of some rural areas of the north-eastern part of southern Africa (http://www.worldbank.org/afr/ikdb/ik_results.cfm); about 500 insect species such as green bugs (*Hemiptera*), termites (*Isoptera*), various caterpillars, crickets, and grasshoppers being known to be consumed (Groombridge and Jenkins, 1992) • Consumption of inland freshwater fishery products; the important food sources in Papua New Guinea, the Solomon Islands, and Fiji (Barnett, 2007) • Consumption of minnows/whitebait (*Omena*), which is cheap and plentiful by the poor people in Kenya's Nyanza Province (Oniang'o et al., 2004)
Agricultural management	• Growing of traditional plants between successive main crops to reduce the build-up of pests and diseases (Owusu et al., 2008; Chua et al., 2010) • Using phosphate rocks as fertilizers to increase soil fertility (http://www.fao.org/docrep/007/y5053e/y5053e00.htm) • Using the Zai method for reclaiming degraded land, harvesting rainwater, and increasing crop yield; hence contribute to water harvesting and make efficient use of plant nutrients (Fairhead, and Scoones, 2005; Fatondji et al., 2006; Aune and Bationo, 2008) • Using a traditional low-cost method to increase the profitability by animal fattening through feeding each ram with 300 g of millet bran and 300 g of cowpea haulms per day (Aune and Bationo, 2008; Ktita et al., 2010) • Utilization of seed priming technique (osmoregulation before sowing) by African farmers to improve crop establishment and increase yield (Harris, 2003; Ali and Talukder, 2008)
Processing practices	• Storing cereal and legume grains in traditional grain cribs after postharvest activities (e.g., drying, threshing, or shelling) to reduce their fiber contents and extend their storage life (http://www.fao.org/docrep/W0078E/W0078E00.htm) • Treating cowpeas and other grain legumes by soaking and boiling, roasting, milling, frying in oil, and steaming to eliminate antinutritional factors and improve their overall consumption values (Oniang'o et al., 2004) • Applying Qorasum (a woman's indigenous food technology) to store and preserve food, particularly milk (Oniang'o et al., 2004) • Application of processing methods such as fermentation, salting, pickling, drying, and smoking for preservation to ensure food safety (Svanberg and Lorri, 1997; Holzapfel, 2002; Sharma et al., 2009; Tiwari et al., 2009)
Others	• Storing yams, cocoyams, and cassava in underground pits after harvesting to extend the shelf life of fresh roots and tubers (Ravi et al., 1996) • Using local equipments (e.g., bullock carts), distributors, and community-based supervision to distribute food in the local context to prevent the major losses of food along distribution line, such as the successful story of food distribution practice in Nepal (Gorjestani, 2000)

direct interaction of people with their local environment (Oniang'o et al., 2004). The proper use of IK as a locally owned and managed resource can contribute positively to developing cost-effective and sustainable survival strategies (Gorjestani, 2000), empowering local communities, and increasing the sustainability of food security efforts (Gorjestani, 2000; Oniang'o et al., 2004; Sen, 2005). In Africa, indigenous practices such as reversing soil infertility through the use of locally available resources (e.g., nitrogen-fixing trees, indigenous rock phosphate) have increased the harvest for tens of thousands of African farmers (Sanchez, 2002). Some other examples of integration of indigenous knowledge and practices in the food production systems are summarized in Table 2. These practices have been demonstrated to be promising and have provided a great opportunity to improve food sustainability. Appropriate applications of these existing knowledge and practices should be well documented to promote the sharing of these practices to benefit the other poor and food-insecure countries (Nah and Chau, 2010).

INSTITUTIONAL STRATEGY TO PROMOTE FOOD SECURITY

Development of appropriate institutional strategies at the national level is one of the keys to attain sufficient food production and help people escape from poverty and hunger. Different laws and standards such as "The Roadmap to End Global Hunger and Promote Food Security Act," "Childhood Hunger Relief Act," "Hunger Prevention Act," and "The Hunger Relief Act" (Landers, 2007; http://actioncenter.org/roadmap; http://www.fns.usda.gov/snap/rules/Legislation) have been implemented for the purpose of alleviating hunger and promoting food security. Implementation of policies specifically aimed at improving the health, nutrition, and social status of girls and women (i.e., poverty-reduction strategy with inequity reduction emphasis) would also need to be a part of the solution, especially for improving early childhood undernutrition (von Grebmer et al., 2010).

Table 3 summarizes the institutional strategies of some selected countries for hunger and poverty reduction in recent decades. Different institutional strategies (e.g., economic and trade policy reforms, liberalization, privatization, commercialization, institutional reform, agricultural reform, improved accessibility to technology and education, and poverty- and hunger-reduction programs) have been implemented for the purposes of reducing poverty, increasing accessibility to affordable, nutritious food, and improving overall economy and food security through agricultural and economic reformations. Moreover, the capacity to formulate and enforce food safety regulations with positive ethical attitudes is also essential to safeguard sustainable food productions. Food safety and sanitation in association with the factors such as environmental contamination (e.g., heavy metal), processing abuses (e.g., aflatoxin), poor social conditions, and lack of safe food preparation facilities are

Table 3 Institutional strategies of different countries for hunger and poverty reduction in the recent decades

Country	Ways to alleviate hunger and poverty
Armenia	(1) Agricultural and economic reforms (e.g., liberalizing trade and price, phasing in a legal framework for a market-oriented economy, commercializing agricultural products, strengthening institutions)—reducing poverty from over half of the population in 1999 to less than 25% in 2007; (2) Modernization of land tenure process in rural areas by the Food Security Program and the Poverty-Family Benefit System—reducing hunger and poverty situations (FAO, 2009b)
Azerbaijan	Microeconomic reforms since 1990s (e.g., privatization of agricultural land and titling, redistribution of assets to the poor)—resulting in higher industrial outputs, GDP increase (up to 250%), maternal and infant mortality decline (by ∼32 and 48%, respectively) between 1995 and 2001 (FAO, 2006; Gentilini and Webb, 2008)
Brazil	Adoption of different policies (e.g., Zero-Hunger Program, Bolsa Família Program)—aiming at improving federal administrative efficiency, generating positive impacts on local economies, improving school attendance, and offering benefits to the extreme poor, while attempting to reduce poverty and increase accessibility to more affordable, nutritious food (USDA, 2004; FAO, 2006, 2009a; Rocha, 2009; http://www.brasembottawa.org/downloads/en/PROGRAMA.PDF)
China	Improvement of infrastructure (FAO, 2003), establishment of equal access to education (FAO, 2003), initiation of institutional reforms (FAO, 1998; Khan et al., 2009), and rapid adoption of research and development (Alston and Pardey, 2006; Khan et al., 2009)—reducing 50.4 million of hungry people (FAO, 2009a), while total population increased by over 170 million between 1990–1992 and 2004–2006 (http://esa.un.org/unpp)
Georgia	(1) Microeconomic stabilization program in 1994 (e.g., monetary and fiscal stabilization, privatization, education reform, health care reform, trade liberalization)—trying to combat corruption, reform legal system, restructure national economy, improve social payments, provide education, and protect environment; (2) Anticorruption, legal and judicial reforms in 2004—trying to remove corruption and preferential treatment, improve social equity and security, and promote legitimate business (IMF, 2003; World Bank, 2005)
Ghana	(1) Economic reform and new policy initiatives in the agricultural sector during 1986−2002 (e.g., privatization of state farms, reduction of subsidies on inputs, removal of commodity price controls)—contributing to an agricultural growth (∼4–5% per year) during 1995–2003 and overall economic improvement; (2) Adoption of high-yield variety crops—increasing food production and availability from 2,000 calories per day in the early 1990s to 2,667 calories per day in 2003 (FAO, 2005c)
Guyana	Economic and trade policy reforms since 1989 (e.g., elimination of price controls in the food sector, liberalization, privatization of the sugar industry, endorsement of a better water resources management)—resulting in agricultural GDP growth (7% per annum) between 1991 and 1995 (Thomas and Bynoe, 2006)
Myanmar	Market-oriented economic and agricultural reforms in the late 1980s—reducing rice procurement price and agricultural implicit taxation, encouraging free trade flows and private sector investments, increasing per capita food production index, allowing farmers to increase sales to markets and exports of some crops, then elevating GDP from the private sector (from 75% in 2000–2001 to 91% in 2005–2006) (Kyaw, 2009)
Jamaica	Promotion of pro-poor policies since 1990s—trying to control inflation, reduce food price, enhance employment opportunities and wage for poverty reduction (Gentilini and Webb, 2008)
Nicaragua	Enactment of good governance and state modernization between 1990 and 1995 (e.g., lowering trade barriers, increasing public spending on poor, reforming the education and health sectors)—increasing income per capita by one-third, decreasing the number of people in extreme poverty by 25%, and reducing inequality (World Bank, 2009)
Nigeria	(1) Microeconomic reformations (e.g., deregulation and privatization in different sectors) and implementation of National Special Program for Food Security (NSPFS) in 2001—contributing to an economic growth over 7% per annum; (2) Under the NSPFS, various technologies (e.g., diversified farming systems, productive agricultural practices, sustainable systems), marketing services, and nutrition and health education being promoted to increase the productivity of rural communities (FAO, 2009b)
Peru	Macroeconomic policies to encourage foreign investments in the early 1990s—contributing to better agricultural and food productivity, increased per capita income, conversion from trade deficit to trade surplus in 2002, and elevation of food supply from 1,993 calories per day in 1990 to 2,571 calories per day in 2002 (FAO, 2005c)
Thailand	Extensive rural development programs by government and non-government agencies (e.g., Farmers Debt Moratorium, Village fund)—aiming to reduce poverty and improve nutrition to meet the basic human needs for the entire population (Office of the National Economic and Social Development Board, 2004)
Vietnam	Policy reforms since the late 1980s (e.g., introduction of new crop varieties, improvement of accessibility to new technology and government investments, subsidies to the credit system)—increasing the production of main staple foods, generating high-income growth and export earnings (i.e., cereal), and thus leading to an overall boost in economic growth and food security improvement across all income levels (FAO, 2005c)

necessary to ensure an uninterrupted supply of food, especially the staple food in poor and food-insecure countries (van de Venter, 2000; FAO, 2005a; WHO, 2009).

Nevertheless, implementation of inappropriate strategy and intervention such as failing agricultural policy, misguided emphasis on food self-sufficiency, and incomplete policy reforms might intensify the hunger crisis and food instability. For example, as of 1993, the International Monetary Fund restructuring program implemented in 36 SSA countries had a negative impact on food production (Ibhawoh, 1999). In Zimbabwe, the removal of government subsidies on agricultural inputs under this program has reduced the capacity of their communities to produce food for local consumption. This has caused chronic malnutrition in 30% of the children under the age of five by the end of the 90s (Narula, 2006). During the production shortfall in 2005, Niger was struck by famine largely due to the government's insistence on the "market-based" policies and refusal to distribute free food to its citizens. On the contrary, Mali was able to escape the famine by changing their policies and subsequently distributing free food to its people in response to their production shortfalls (Narula, 2006). In reaction to the inflated high food prices since the mid-2000s, some food exporting countries have adopted a variety of export-reducing policies (e.g., export restriction, export bans and tariffs), causing reductions of incentives for the key producers to invest in the domestic agricultural sector, declines in the food supply regardless of the global food demand, and further elevations in world food prices (Collier, 2008; Trostle, 2008).

In fact, politicians and policymakers do have the power to solve the food crisis economically and politically. Three complementary ways for them to achieve this mutual goal are expanding large commercial farms, ending the GM crop bans, and abating farm subsidies (e.g., US subsidies on bioethanol) (Collier, 2008). However, if the world governments continue to implement policies that could ultimately engender food crisis, and then recklessly enforce these policies in despite of learning their serious potentials to cause mass starvation, a further famine can be inevitable. Without a doubt, the overall success of hunger prevention and food security requires the implementation of appropriate institutional plans and subsequent reinforcing actions.

CONCLUSIONS

In this battle against world hunger and food imbalance, challenges such as diminishing natural resources, aggravating natural disasters, emerging climate changes, and persisting poverty, illiteracy, and disease are posing great threats to the world's efforts to ensure food security and alleviate the hunger crisis. In the face of these challenges, the goal to combat hunger should be achieved not only by increasing food availability but also by optimally integrating all different aspects of science, technology, and education to form a multifaceted strategy to comprehensively tackle world food imbalance, hunger, and malnutrition from all angles. Nevertheless, the intersecting and conflicting issues associated with the broad range of solutions or propositions as discussed above must be considered beforehand to avoid unnecessary interferences and obstacles in defeating hunger hereafter. All these international efforts will doubtlessly pave the way to a sustainable and equitable food security, especially for the poor.

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