Systems Solutions to Global Food Security Challenges to Advance Human Health and Global Environment Based on Diverse Food Ecology **

Kalidas Shetty, Ph.D.
Founding Director of Global Institute of Food Security & International Agriculture,
Professor of Plant Science at North Dakota State University, Fargo, North Dakota, U.S.

Summary

On a global level, there is rapid emergence of diet-linked chronic diseases that represent a new reality of food security. This recent global increase in diet-linked noncommunicable chronic diseases (NCDs) places a heavy burden on long-term health care management and overall costs, thus consuming higher levels of national health care budgets. All NCDs involve a metabolic malfunction that manifests itself in enhancing oxidative stress (i.e., oxygen function breakdown) at many cellular and organ levels. Food crop-based diets designed for management of oxidative stress will be an important part of the overall solution to combat NCDs. The most cost effective of these metabolic innovations for NCDs is improved design of food crops based on agroecological diversity and enhanced redox-linked bioactive components (i.e., oxygen stress protecting compounds) that can prevent oxidative stress and thus mitigate NCDs. Such food design must contain both macronutritional and micronutritional ingredients, including bioactive compounds that can counter oxidation-linked malfunctions of NCDs. Such enriched foods are also essential in advancing community-wide nutrition and health, while concurrently increasing the agroecological diversity (i.e., plant biodiversity) of local food crops. All these efforts greatly benefit the global ecology.

Current realities

The current global food and nutritional security model must be improved to generate adequate global food production from a wide diversity of crops that will meet macro/micronutrient needs along with phytonutrients (e.g., phenolic antioxidants) to counter obesity-linked NCDs. NCDs represent a large financial burden on health care systems worldwide, a burden that has been increasing in recent years. Given that NCDs at their core have a metabolic malfunction that includes increased oxidative stress, solutions that enhance natural antioxidants to combat this stress would have a substantial impact on NCD prevention. Although recent strategies by such agencies as the United Nations (UN) and the U.S. Agency for International Development (USAID) have included a focus on nutrition, their focus has been limited to the traditional macro/micronutrient model that excludes the bioactive components of food responsible for limiting NCDs.

The current economic and production practices favor highly processed carbohydrate-enriched foods and are dependent on a narrow selection of major cereal crops. These cereal crops are less resilient and robust in responding to and dealing with climate change extremes because they are bred for yields rather inducible responses to abiotic stress (e.g., salinity and temperature). In addition, global food security currently is dependent on petroleum fossil fuel-based nitrogen that contributes to the unsustainable addition of nitrogen wastes, which affect ecology and human health. Globally, nitrogen in the soil has doubled in the last 100 years. Excess nitrogen is a third ecological dimension of the food cycle — in addition to increasing carbon emissions and poor water quality — that worsen human health in terms of vascular hemoglobin function and global ecology (e.g., worsening algal blooms and associated toxins).

At the sociopolitical level, subsidies favoring a restricted choice of cereal crops over balanced co-production of pulses (i.e., legumes) impair nutritional security with a breakdown of the agroecology, especially with regard to biodiversity of healthy crops and soil biology. Overall, the lack of food diversity, from an unsustainable ecology focused on restricted crop choices and excess fertilizer application, coupled with high consumption of hyper-processed carbohydrates

and lipids, without micronutrients and oxygen stress protecting phytonutrients, is increasing obesity-linked NCDs globally. Answers to the above challenges affecting global food security require integrated, systems-based solutions that use nutrition-based food security for the betterment of human and animal health and for an improved agroecology that is based on crop and food diversity.

Scientific opportunities and challenges

Integrated systems-based platforms are needed for advances in life sciences. Such integration will extend into global food security challenges, where systems strategies will be used to assist in the development of biological-based solutions in a post-genome era. The calorie model of limited agricultural commodities is incomplete, as increased calorie density from highly processed foods does not account for the variability in oxygen function responsible for cellular energy generation from foods. Food components must not only provide basic macro/micronutrients, but also counter oxygen malfunction through compounds such as phenolic phytochemicals (i.e., oxygen stress protectors), which are removed during food processing.

The above point must be addressed by encouraging soil health by (i) improving soil rhizosphere microflora (i.e., the beneficial microflora in the root zone), (ii) enhancing phenolic antioxidant responses in seed germination, and (iii) growing crop varieties, such as legumes and cereals, with beneficial phenolic antioxidant bioactivities for countering oxygen malfunction. The development of redox-balancing foods, which protect against oxidative stress-linked breakdown, through less-processed crops that contain enhanced phenolic antioxidants can serve as a systems-based critical control point to balance metabolic dysfunction (i.e., fewer NCDs). Such an integrated system improves soil health and microflora that affects human health-relevant oxygen stress by using phenolic antioxidants. These enriched whole grain foods can be the foundation for enhanced agroecology, food production, food security, energy crops, and human health. Integrated sustainability of these systems and challenges across the global agroecology and rural and urban communities is essential. Such a foundation in systems logic is key to addressing food security challenges, while also simultaneously addressing ecological breakdown and human health.

From this systems-based foundation of redox-balancing foods, crop metabolic innovations must emerge. This overall approach has the potential benefit of addressing both crop-production challenges and improving their resilience to climate change. These integrated systems must be part of overall solutions to more-resilient and multi-purpose agricultural systems that better address global food security, through crop and food diversity models, both for ecological sustainability as well as an improved approach to addressing the challenges of human health.

Policy issues

Bioactive-enriched and microbial-based bioprocessed food crops can be integrated as a part of comprehensive solution where bioactive ingredients provide multiple functions such as countering critical steps of NCD emergence:

- Food diversity must advance components of local food production, including technologies for non-seasonal indoor production of bioactive fresh foods using energy from waste recycling.

- Fruits, vegetables, greens, pulses, and herbs must be developed with respect to nutritional-linked health outcomes and NCDs and suitably developed as “crops for health.”

- National, state and local administrations must continue to shift food security-linked health policies towards integrated nutritional security-based health outcomes, focused both on traditional malnutrition challenges and emerging NCDs.

- International agencies such as Food and Agriculture Organization (FAO) and the World Health Organization (WHO) must coordinate efforts to work with national bodies to inform political and sociopolitical discourse on evidence-based scientific rationale regarding moving food subsidies away from refined carbohydrates and traditional calorie-focused food security models.

- International bodies linked to the United Nations must integrate "crops for health" and "foods for health" as a diversified value-added agricultural development platform for economic advancement of local communities.

- Post-harvest technologies must be advanced globally and integrated well into crops/foods for health and reduce waste of quality foods that are major antidotes for malnutrition and NCDs.

- Crops for health varietal development and related food-processing technologies must develop agricultural systems for climate change resilience and robustness, using a dual function bioactive crops model based on redox biology (i.e., oxygen stress balance in cells), in which oxygen stress-protecting bioactives for health can also provide crop production resilience in response to climate change.

References

Paliyath, G., and Shetty, K. (2011) Functional Foods, Nutraceuticals, and Disease Prevention: A Window to the Future of Health Promotion. *Functional Foods, Nutraceuticals and Degenerative Disease Prevention* (Paliyath, G., Bakovic, M., and Shetty, K. (Eds). John Wiley & Sons, NY. Pages 3-10.

Sarkar, D., Ankolekar, C., and Shetty, K. (2012) Functional Food Components for Preventing and Combating Type 2 Diabetes. *Emerging Trends in Dietary Components for Preventing and Combating Disease.* Edited by Patil, B. et al., ACS Symposium Series. Volume 1093. March 6, 2012 (Web). Chapter 20, pages 345-374.

Sarkar, D., and Shetty, K. (2014) Metabolic Stimulation of Plant Phenolics for Food Preservation and Health. *Annual Review of Food Science and Technology*, 5: 395-413.

*** A policy position paper prepared for presentation at the conference on Food Safety, Security and Defense: Focus on Food and the Environment, convened by the Institute on Science for Global Policy (ISGP), on October 5-8, 2014 at Cornell University, Ithaca, New York, U.S.*