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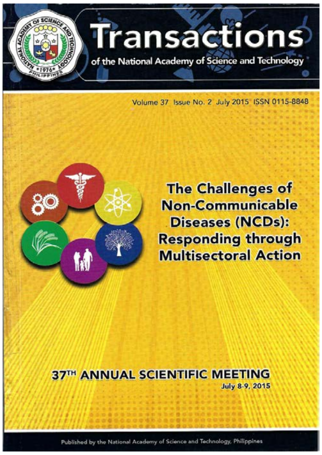

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AGRICULTURE-HEALTH CONVERGENCE: SYNERGY IN MANAGING NON-COMMUNICABLE DISEASES

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The World Health Organization (WHO) defines health as "a state of complete well-being and not merely the absence of disease or infirmity" (WHO 1946). The use of the term "complete" in this definition has been criticized (Huber and others 2011), one reason being that it disregards the fact that most people manage to live with chronic diseases. This is made possible through public health interventions. i.e. improved nutrition, hygiene, sanitation and health care. Thus, particularly in an age of increasing lifespan, a dynamic construct of health that integrates adaptive measures to deal with chronic diseases to enhance the quality of life, e.g. dietary changes, is needed. Although much attention has been given to the three major NCDs, i.e. cardiovascular diseases (CVDs), neoplasms and diabetes, increased attention to other NCDs is warranted to safeguard the quality of life, particularly of the elderly (Lopez and others 2014).

Improved nutrition, along with personal hygiene and environmental sanitation, plays a key role in the management of non-communicable diseases (NCDs)[1], which in the Philippines, accounted for 67% of total deaths in 2014 (WHO 2014). The National Nutrition Survey from 1993 to 2013 showed that 1 of every 5 adult Filipinos (≥ 20 years) is hypertensive. The prevalence of high fasting glucose increased from 3.4% in 2003 to 5.4% in 2013 (FNRI 2014).

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[1] The WHO considers "chronic" synonymous with non-communicable diseases (WHO, 2015). The term "chronic" as used in this paper excludes communicable chronic infections.

It has been estimated that 80 % of NCDs can be prevented through primary prevention approaches, such as behaviour modification (Kaplan 2000). Improved nutrition exemplifies a route to more effective NCD management, which appropriately involves measures that usually lie outside the boundaries of conventional healthcare systems (Dube and others 2012).

The 2011 conference, "Leveraging Agriculture for Improving Nutrition and Health", organized by the International Food Policy Research Institute, pointed to the deployment of agriculture in addressing nutrition and health challenges. Agriculture's role in supplying food, providing income and driving economic growth contributes to public health improvement (PandyaLorch and others 2011). The influence of diet in defining the expression of genetic susceptibility to NCDs was the subject of a Joint WHO/Food and Agriculture Organization (FAO) Expert Consultation in 2003, which considered diet in relation to the macroeconomic implications of public health recommendations concerning agriculture (WHO 2003). It is, therefore, in improved nutrition that agriculture and health converge.

The agriculture-public health link is implicit in the 1996 World Food Summit (WFS) definition of food security, i.e. "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996). The FAO highlights the distinctive relationship between food and nutrition in meeting nutrition-related millennium development goals, and fully recognizes the key role played by food and agriculture-based approaches to address the problem of malnutrition and improving nutrition in general (Thompson and Amoroso 2015). Although the WFS definition conveys the message that food security can be achieved only when the three requirements of sufficiency, food safety and nutrition are met, Swaminathan called for a shift to the concept of "Nutrition Security" (Swaminathan and Bhavani 2013), as the end goal of food security is health. Thus, measures to ensure food security provide insights as to how the agricultural sector might be more effectively mobilized to manage NCDs.

The four dimensions of food security: A roadmap to agriculture and health convergence

Agriculture provides the most basic material needs of food, clothing and shelter, with food having the greatest impact on NCDs (WHO Regional Office for Europe 2013; WCRFI 2014). The four dimensions of food security, i.e. availability, physical and economic access, utilization and stability (FAO 2008; United Nations 2010), provide a roadmap to the management of NCDs through nutritional interventions. These dimensions have figured prominently in international forums that have covered nutrition, food systems and health in a single platform, e.g. the Second International Conference on Nutrition (ICN2) convened in 2014 (FAO-WHO 2014).

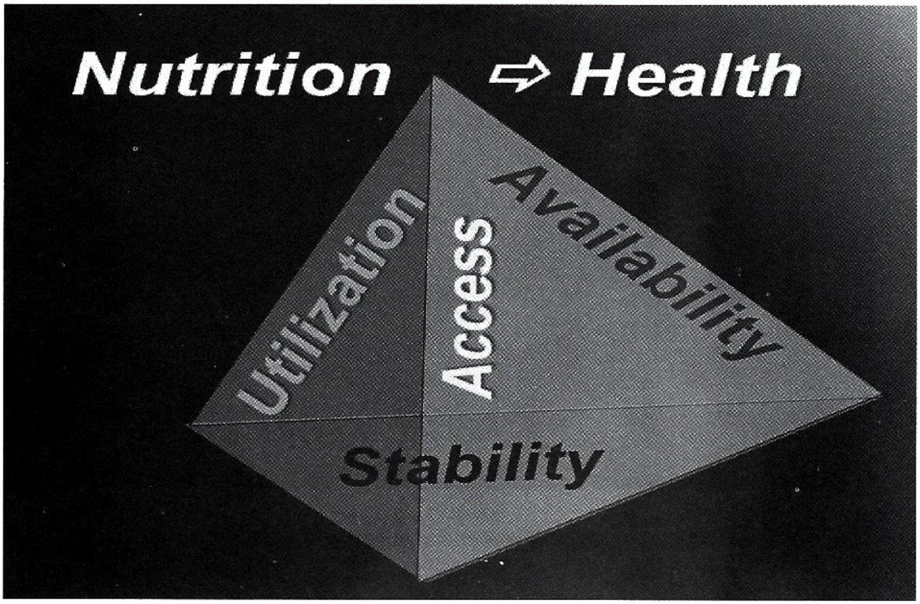

Figure 1. The dimensions of food security

Physical availability of food

This dimension covers the supply side of food security and may be considered the starting point for linking agriculture to health (Fig.1). Availability is defined as the dimension that depends on the "level of food production, stock levels and net trade", or the capacity of the production system to meet food demand (FAO 2008). Among other factors, availability is determined by how well farmers respond to market demands, given technological, environmental, socio-economic and cultural factors (Schmidhuber and Tubiello 2007). It is in this dimension, particularly at the level of the farming household, that convergence leading to synergy between agriculture and health can be realized.

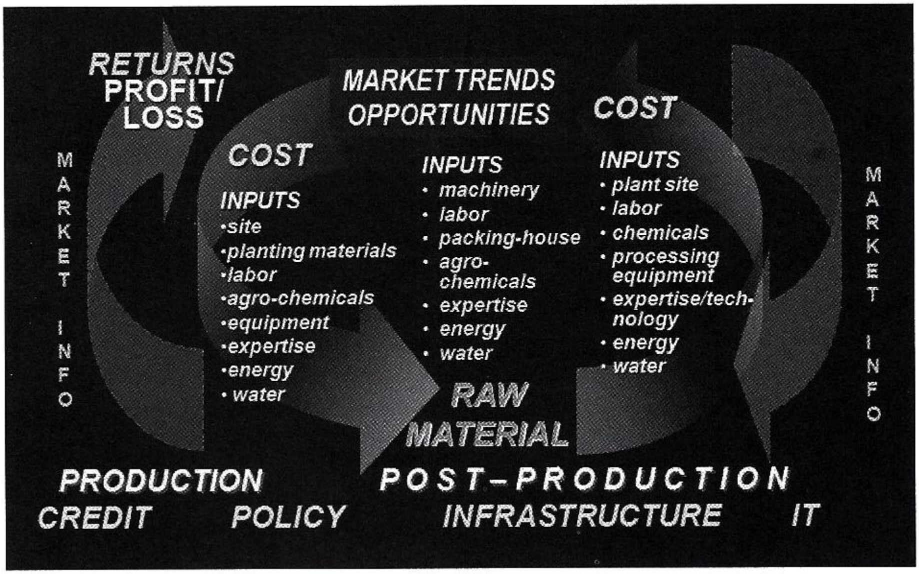

Figure 2. The production-marketing continuum (modified from FAO, 1989)

Economic and physical access to food

The contribution of diet to public health is defined by the level of food security in the household, which depends on the latter's physical and socio-economic capacity to access available food appropriate for a nutritious diet. This capacity depends on the household's initial endowments and endeavors, and/or government intervention (Swaminathan and Bhavani 2013).

Agriculture-based enterprises provide opportunities for greater economic access to food, particularly for farming households, and, like all enterprises, begin and end with the market. Market opportunities for agricultural produce are created by the promotion of healthy diets (Fig. 2), leading to benefits to both public health and agriculture.

Utilization

Full utilization of food for health can be achieved through appropriate and safe food preparation, food choices and intra-household distribution to meet the dietary requirements of individuals. A favourable social environment and an effective healthcare system for disease prevention or management are requisite to the efficient utilization of food by individuals at the biological level.

Stability

The above three dimensions of food security are interactive (Fig. 1) and create the potential for food security for the community, the family and the individual. However, this potential can only be realized if the food security status is reliably sustained at all levels. Food insecurity is experienced when instability in the three dimensions results from adverse climatic conditions, political instability, or economic factors such as unemployment/underemployment and rising food prices (FAO 2008)

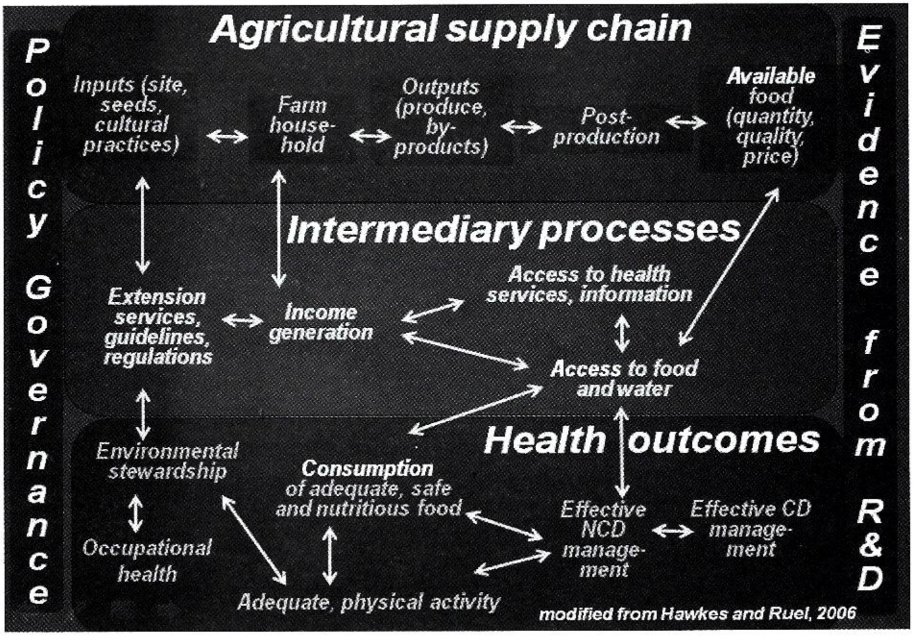

Figure 3. Conceptual framework linking agriculture to NCDs (modified from Hawkes and Ruel, 2006)

The four dimensions of food security and management of NCDs

The framework linking agriculture and health as presented by Hawkes and Ruel (2006) focuses on the bidirectional character of the linkage, illustrating the role of agriculture in the management of NCDs and other health problems, while noting the role that the health sector plays in sustaining the productivity of agriculture. Without explicitly identifying food security as the pervasive concept, the framework integrates the four dimensions of food security (Fig.3). Availability is defined by the agricultural supply chain; physical and economic access enables communities, households and individuals to utilize available food; health outcomes are achieved through appropriate utilization; and policy and process governance ensure stability by mitigating the adverse effects of changes in the physical and socio-economic environment. From this framework one can identify areas for intervention, whether these be in research for evidence-based recommendations, extension services, or policy to support either or both of the roles of agriculture and health in managing NCDs. In 2012, the FAO convened a consultation involving 30 international organizations and development institutions concerned with leveraging agriculture to maximize the impact of nutrition. The consultation led to the publication of the guidance document "Synthesis of guiding principles on agriculture programming for nutrition" (FAO 2013a). Without explicit reference to the four dimensions of food security, the guiding principles fall neatly into a framework based on these dimensions.

The above framework is consistent with calls for a multi-sectoral systems approach to the management of NCDs made in a high-level meeting of the UN General Assembly in 2014 (UN 2014). In this meeting FAO emphasized the need for the analysis of the entire food system from production through to consumption to ensure that the entire system is geared towards healthy nutrition and that approaches to the problem of NCDs can be sustained. It is through a multi-sectoral systems approach that mutually beneficial and reinforcing relationship between agriculture and health can be established. It is through such relationship that synergy in addressing the double burden of malnutrition can be achieved. Although all the dimensions will be covered in this paper, greater emphasis will be given to availability and utilization.

Primary Production and Availability

Diversity of agricultural produce available to address under- and over-nutrition

The term "food security" has been associated with the notion of sufficiency in grains (Shaw 2007). In the 2011 Asia-Europe Meeting (ASEM) High Level Conference on Food Security, for example, country presentations, including that of the Philippines, focused on self-sufficiency in rice (ASEM 2011). This is understandable, as rice contributes the highest proportion of calories to the Southeast Asian diet, with most countries relying on this staple for at least half their caloric intake (FAO 2008). Despite the emphasis on rice in relation to food security, the prevalence of chronic energy deficiency (CED) among adults in the Philippines was10% in 2013 (FNRI 2014). Ironically, urban areas suffer from a greater prevalence of both CED, and overweight/obesity compared to rural areas. Approaches towards addressing the double burden of under- and over-nutrition are not straightforward from a health (physiological) perspective (Dans and others 2011), and from a socio-economic perspective as well. The WHO identifies NCDs as a fundamental development and socioeconomic issue, affecting both rich and poor alike. However, NCDs lead to more serious and inter-generational consequences among the poor (WHO 2011), as exemplified by observations supporting the Barker hypothesis on maternal malnutrition and adult onset NCDs in the offspring (Gupta and Jani 2015).

Agricultural production, overall, needs to be geared towards combating NCDs, a move that goes well beyond producing needed calories. Burchi and others (2011) drew attention to the need to go beyond adequate caloric intake and address both hunger and under-nutrition or "hidden hunger". Hence, the need for the green revolution's focus on staples in the 70's to broaden and include the alleviation of micronutrient deficiencies. This view reflects what was originally envisioned in the 1943 declaration on food security, highlighting the requirement for foodstuffs other than cereal staples, e.g. fruits and vegetables (FAO 1995). Sir John Boyd Orr, the first FAO director-general and a nutritionist, envisioned an international coordination of food production, where advantage is to be gained by many countries in diversified farming, concentrating on the more perishable crops needed for health, while leaving a greater proportion of the production of more durable crops, like cereals, to countries best adapted to produce, store and transport them (Shaw 2007). This proposal, which, unfortunately, was not approved by the FAO, was followed by others on food reserves, which concentrated on more durable staples. Starch is the main constituent of staples, which can be broken down to simple carbohydrates, the most readily available source of calories.

Carbohydrates lack the metabolic advantage provided by other calorie sources in staving off the global epidemic of overnutrition leading to obesity and its consequences (Feinman and Fine 2004). A review of published clinical and experimental studies has shown that restricting dietary carbohydrates decreases blood glucose levels and caloric intake; is better for weight loss, with restricted carbohydrate diets being more closely adhered to compared to other dietary interventions; provides control of plasma saturated fatty acids, reduces serum triglycerides and increases high-density lipoprotein; frequently eliminates the need for medication in type 2 diabetes without incurring the side effects associated with intensive pharmacologic treatments (Feinman and others 2015). Feinman and colleagues support carbohydrate restriction as the first approach to treating type 2 diabetes and as the most effective adjunct to pharmacologic treatment for type 1 diabetes.

The focus on staples has given rise to less diversified rural economies and diets (AVRDC 2011). Rice-based farming households might not have access to the variety of food needed for dietary diversity. A significant body of evidence supports recommendations on dietary diversity not only for rural communities but for all consumers. An epidemiological study of dietary diversity based on five food groups, i.e. dairy, meat, grain, fruit, and vegetable, in relation to mortality in the US revealed an inverse association (Kant and others 1993). A key finding of the study based on data from the First National Health and Nutrition Examination Survey (NHANES) was that the consumption of ≤ 2 food groups is associated with an excess mortality risk of 50% in men and 40% in women. The authors noted that a varied diet is consistent with dietary guidelines that emphasize reduced dietary fat and increased dietary fiber intake. The results of a follow-up NHANES suggest an increased risk of CVD and cancer mortality associated with diets that omit several major food groups (Kant and others 1995).

In the rural elderly population of Sri Lanka, dietary diversity in terms of both the simple count of food items and food groups has the potential of serving as proxy indicators of nutrient adequacy (Rathnayake and others 2012). Among the elderly in Taiwan, dietary diversity was associated with lower emergency and hospitalization utilization, and expenditures (Lo and others 2013). A study in Eastern Uganda identified low dietary diversity as one of the risk factors in the development of diabetes among those aged 35 to 60 years (Mayega and others 2013). Considering the benefits of dietary diversity, Drescher and others (2007) recommend that indices for healthy diets consider number, distribution and health values of food elements, which are reflected in "Pinggang Pinoy" (DOH 2014) and the 10 *Kumainments* of the National Nutrition Council (NNC 2014). Much can be learned from culinary traditions, e.g. serving a daily total of 35 different ingredients in Japanese homes (Kitagawa personal communication), the five colors in Korean cuisine (Agriculture and Agri-Food Canada 2011) or the pairing of dishes in the Philippines (PinoyExchange 2015), which help ensure dietary diversity and balance. The use of herbs, spices and condiments can contribute not only to modulate salt intake, but also enhance dietary diversity.

Evidently, agriculture and fisheries can contribute much more to programs for improved health through the year-round availability of diverse and safe foods essential to good nutrition (FAO 2014; Frison and others 2011). The seasonality of a wide range of nutrient-rich food depends on the interaction between genotype and the physical environment, and determines the type of food available at a given time of the year. The yield of a range of crops/varieties and the productivity of food animals (e.g. fish, eggs or milk supply) are subject to seasonal and climatic variations. Breeding and selection have been instrumental in extending the period of availability of these food products. Technological developments in aquaculture management, formulation of inputs (seeds, feeds, fertilizers and veterinary/crop protection agents) and cultural techniques, e.g. flower induction in mango and calamansi, have led to increased reliability of supply of nutrient-rich produce (Baroja 2010; Protectia 2014).

The consumption of a variety of fruits and vegetables leads to favorable nutrient interactions. The enhanced absorption of carotenoids from salads and salsa containing avocado, for example, has been attributed to the fruit's oil content (Unlu and others 2005). Avocado contains oleic acid (C18:1), equivalent to about 2 tablespoons of olive oil/136-g fruit (Dreher and Davenport 2013). Recently it has been shown that, for overweight and obese individuals, a daily moderate fat diet low in saturated (SFA), with a high level of monounsaturated fatty acid (MUFA) coming from an avocado leads to greater reduction in low density lipoprotein (LDL) cholesterol and emerging cardiovascular risk factors than a high MUFA diet without avocado (Wang and others 2015).

Health benefits from plants can be attributed to a number of bioactive phytochemicals (Hu 2003) and their synergistic interactions (Liu 2013). Potassium, which occurs with organic anions in fruits and vegetables, confers a range of health benefits in terms of blood pressure reduction as well as heart, kidney, bone, and other tissue health. In contrast, potassium chloride supplements may benefit blood pressure, but not bone health (Weaver 2013). Plant-based foods provide dietary fiber, affording such benefits as serum cholesterol reduction via inhibited cholesterol absorption from the gut and increased fecal excretion of bile acids (Delaney and others 2003). Additional benefit may be derived from the fiber from whole plant-based foods compared to fiber added to drinks in slowing gastric emptying (Slavin and Lloyd 2012).

Based on a review of studies on diet Tuso and others (2013) recommend that physicians encourage the increased consumption of whole, plant-based foods (primarily fruits and vegetables) and reduced intake of animal products. This is consistent with the recommendations of the Panel that reviewed evidence on food, nutrition, physical activity and cancer (World Cancer Research Fund 2007), as well as the Dietary Approach to Stop Hypertension (DASH) diet (Lin and others 2003; NIH 2014). Plant-based foods are good sources of potassium, magnesium and fiber, which are key nutrients in the DASH diet. In 2004 a WHO/FAO Workshop on Fruit and Vegetables for Health recommended a minimum consumption of 400g of fruit and vegetables daily for the prevention of NCDs and several micronutrient deficiencies, especially in less developed countries (WHO/FAO 2004).

Plant-based foods conferring such health benefits as reduced risks of CVD, obesity and type 2 diabetes, can be sourced from a widely diverse group. Indigenous (Pudasaini and others 2013), heirloom (Rodriguez Burruezo 2005) and landrace (Raigona and others 2008) varieties represent the range of relatively untapped gene pools that can be used to ensure dietary diversity. Varieties of quality protein maize (QPM), for example, have been developed through conventional breeding based on the combined use of the o2 gene of soft opaque-2 maize varieties and genetic modifiers (Vasal 2000). QPM varieties combine good protein quality with the inherent nutritional and agronomic advantages of corn.

The potential contribution of some traditional species/varieties to health are underestimated and underutilized. Sweet potato (*Ipomea batatas*) tops, which can be grown as ground cover, or in urban gardens, are a good source of antioxidants (Sun and others 2014; Johnson and Pace 2010; Chao and others 2013; Chang and others 2010), and have been shown to induce apoptosis in prostate cancer cells *in vitro* and in mice (Karna and others 2011). Yambean (*Pachyrhizus erosus*) is a low-calorie root crop with edible pods, and is a good source of inulin, vitamins, as well as potassium and other minerals. Intercropped with rice or corn, it provides the added benefit of restoring and maintaining the nitrogen status of the soil (Sorensen 1996; Woomer 1979). "*Lutong Filipino: Mga Katutubong Gulay*" (FNRI 2011) aims to expand the utilization of a number of indigenous vegetables in the Philippines, some of which might be appropriate for production in home, school or community gardens. These gardens can be instrumental in enhancing year-round availability of nutrient-rich vegetables (FAO 2013a).

Fully ripe *bignay* (*Antidesma bunius* L. Spreng) contains anthocyanins which are retained after baking, and shows potential functionality in terms of antimicrobial action and antioxidant effect (Lizardo and others 2015). Besides wine (Sales and Raymundo 1983), *bignay* can be used in various forms, including a spray-dried powder that retains its color when dissolved in water (Raymundo unpublished). Avocado is widely available in the Philippines, but has not been developed as a major fruit crop for lack of a widely grown local cultivar. A multi-national company has recently introduced the cultivar California, 'Haas'. A wide range of wild fruits in the Philippines has yet to be fully exploited for health benefits (Chua Barcelo 2014; Magdalita and others 2015).

Fish is a major protein source in the Filipino diet, contributing 42.5 % of the daily animal protein intake (Kawarazuka 2010). Fish protein is superior to plant-based protein in terms of digestibility and amino acid profile. Fish is rich in Vitamin A, calcium, iron and zinc, and is a good source of the omega-3 fatty acids, eicosapentaenoic acid (EPA, C20:5, *n*-3), and docosahexaenoic acid (DHA, C22:6, *n*-3). Omega-3 fatty acids have anti-inflammatory effects, and, therefore, play an important role in the manifestation of chronic diseases including coronary heart disease, diabetes, arthritis, cancer, osteoporosis, mental health, dry eye disease and age-related macular degeneration (Simopoulos 2006, 2008). Fish also contributes to iodine intake, although its content is much lower than that of seaweed (Tokudome and others 2002). Fish for a healthy diet can be more reliably sourced from fish farms where the environment and feeds can be better controlled (Thilsted 2014), leading to a more constant nutrient composition in farmed fish relative to captured fish.

Livestock and poultry contribute to dietary diversity, with some animal-based food conferring distinct health benefits, as well. They serve as the main food sources of high quality protein, minerals and the more bioavailable form of vitamin D, cholecalciferol or vitamin D-3 (Schmid and Walther 2013). Thus, with the exclusion of animal food in their diets, vegans are advised to regularly consume calcium, vitamin D, vitamin B-12 and DHA-fortified foods (Craig 2009).

Eggs have been considered an inexpensive functional food, with an exceptional nutritional profile, good protein quality and low total fat. Lack of evidence for an adverse effect of egg on endothelial function in hyperlipidemic adults has been taken as mitigating the "association between moderate egg consumption and increased cardiac risk" (Njike and others 2010). A daily intake of eggs was found to enhance the anti-inflammatory effects of a carbohydrate restricted diet in overweight men, increasing the anti-inflammatory and anti-atherogenic hormone, adiponectin, while decreasing the C-reactive protein, which is associated with an increased risk for chronic diseases (Ratliff and others, 2008). Eggs are a major source of lecithin, from which choline is derived and can be considered an essential nutrient. A Japanese study showed that limiting dietary cholesterol leads to a decreased consumption of dietary sources of lecithin as well (Ishinaga and others, 2005). Dietary guidelines limiting egg consumption are based on the association between elevated plasma cholesterol and CVD risks. However, dietary intake of cholesterol might not be the primary culprit in cholesterol-related CVD risks. Age-related increases in plasma cholesterol levels, for example, have been attributed to reduced elimination of cholesterol as bile acids, and decreased clearance of plasma LDL cholesterol, commonly referred to as "bad cholesterol". The development of hypercholesterolemia in the aging rat has been related to a decline in hepatic cholesterol degradation rather than changes in cholesterol absorption (Galman and others, 2007). A more recent study found an inverse association between cholesterol efflux capacity and incident atherosclerotic CVD in a cohort study based on a population free from CVD at baseline. This study indicated that the anti-atherosclerotic effects of high density lipoprotein (HDL), commonly referred to as "good cholesterol", are associated with its key function of promoting reverse cholesterol transport from the periphery to the liver or cholesterol efflux capacity (Rohatgi and others, 2014). The liver then converts excess cholesterol to bile acids for elimination in the feces as bile salts. Significantly lower bile acid excretion has been reported in adult patients with coronary artery disease (CAD) compared to non-CAD patients (Charach and others, 2011).

Biodiversity as key to availability and dietary diversity

Documentation and conservation measures (Johns 2001), along with the generation of food composition data from wild and indigenous species (Nesbitt 2010), are needed to sustainably derive dietary benefits from biodiversity. Cognizant of the impact on biodiversity of negotiations related to the agreement on agriculture, World Trade Organization (WTO) members have considered the link between biodiversity, on the one hand, and food, rural development, nutrition and health, on the other, in crafting targeted subsidies that support research and development, domestic food aid and environmental programs considered as having minimal trade distorting effects (ICTSD 2006). Developing countries like the Philippines can factor in the link between biodiversity in agriculture and health in targeted consumer subsidies, while identifying special products important to vulnerable farming communities.

Availability as affected by nutritional quality and food safety

Availability can be adversely affected by poor nutrient quality and contamination of agricultural produce with food safety hazards. The selected varieties, quality of inputs, and cultural practices have the potential to enhance or diminish the contribution of food to health (Hornick, 1992; Maki 2006). For example, it is well-known that the levels of lycopene, an antioxidant, decline in tomato when temperatures during fruit growth exceed 32.2 °C, or when harvested fruits are subjected to extended field holding during the summer months (Garcia and Barrett 2005). Lycopene in greenhouse tomatoes was found to increase linearly with potassium in the nutrient solution, but the response depended on genotype and temperature (Serio and others 2007), although genotype x environment interaction in tomato was found to have low heritability (Panthee 2012). Innovations in both cultural management and crop improvement have enhanced the levels of nutrients in agricultural crops (Newell-McGloughlin 2008). Davis (2009), however, presented evidence for dilution effects in minerals, vitamins, protein and other bioactive constituents in some food groups, especially vegetables, selecting for high yield.

Food safety, like nutritional quality, is established in the farm, and depends on the biotic and abiotic factors in the production site or source. The eggs of parasitic helminths present health risks to consumers of salad vegetables, depending on whether strict hygienic cultural practices, e.g. Good Agricultural Practices or GAP, are observed or not (Klapec and Borecka 2012). Malnutrition caused or aggravated by parasitic infections by food-borne helminths is well-known (Stephenson and others 2000), and the consequences can be intergenerational, particularly when women of child-bearing age are affected (Steketee 2003). The phytochelatins present in the popular vegetable, *kangkong* (*Ipomea aquatica*), for example, enable the plant to bioaccumulate heavy metals and thrive even in heavily polluted soil and water (Ahmad 2010). Some of these metals are effectively translocated from root to shoot. In some sites in the Bangkok region, for example, the highest levels of Hg (partly or totally as methyl mercury) found in leaves and stems were 1,440 μg/kg dry wt and 422 μ/kg dry wt, respectively, posing a threat to children and foetuses (Gothberg and others 2002). Exposure to mercury by consuming bioaccumulating vegetables needs to be considered along with exposure through other contaminated food, particularly fish (i.e. shark, swordfish and tuna), a major source of methyl mercury. Pregnant women are cautioned to avoid these species, as the fetus is vulnerable to the adverse effects of methylmercury (Jarup 2003).

Safety starts with site selection, and if either or both nutritional quality and safety are compromised by environmental factors or cultural practices, availability of food for health is covertly compromised as well. Selenium, an antioxidant, can accumulate to toxic levels in plants grown in soils with naturally high levels of this mineral (Tinggi 2005). Nitrate accumulation in plants is species-dependent, but the level in leafy vegetables is also influenced by environmental factors (Cavaiuolo and Ferrante 2014). Risk assessment studies show that the nitrate levels in arugula (*Eruca sativa* L.) warrant a caution to moderate consumption, as an intake of more than 47 g of arugula at the median nitrate concentration of 4.6 g/kg would exceed the acceptable daily intake for Europeans on top of exposure from other sources (EFSA 2008). Although arugula was not included in the risk assessment undertaken by the Hong Kong Centre for Food Safety (CFS), the assessment concluded that the nitrate and nitrite levels found in commonly consumed vegetables were not likely to pose any immediate health risk to the general population (CFS 2010). Most of the dietary nitrate (about 85%) comes from vegetables, and it has been proposed that the beneficial effects of vegetables might be attributed, in part, to their nitrate content (Lidder and Webb 2012). The physiological role of nitrate and nitrite in maintaining vascular and immune functions have been demonstrated (Hord and others 2009).

The inappropriate and excessive use of pesticides on vegetables, e.g. eggplants sprayed 20-72 times, is a significant food safety concern in the Philippines (Eusebio, 2014). Eggplant farmers from Sta. Maria, Pangasinan were observed to apply 25 commercial brands of insecticides, 2 of which belong to category I (highly toxic), and 9 to category II (Lu, 2014). Food is one route to indirect, generally low-level pesticide exposure, which is more likely than direct exposure for most consumers. Chronic health risks are difficult to assess in the case of such chronic, low-level exposure. As pesticide exposure through food is dependent on dietary patterns, maximum residue levels (MRLs) need to be established for a specific population. In practice, the MRLs established by the Codex Alimentarius are frequently used provisionally. The monitoring of pesticide residues in food is needed to ensure that regulations covering pesticide application based on MRLs are followed, which, in turn, should lead to diminished apprehensions regarding the safety of fruits and vegetables. The observation that some farmers routinely reserve rows of unsprayed vegetables for their family's consumption is a common concern for a number of ASEAN countries. Public and private investments in laboratory equipment, training and sampling operations are needed to ensure that the needed residue monitoring programs are in place (De Mata 2014).

Although a number of insecticides are suspected human carcinogens, carcinogenicity has been established only for those containing arsenic (Alvanja and others 2004). However, a number of pesticides have been shown to act as endocrine disruptors, which may contribute to cancer, diabetes, obesity, and infertility (De Coster and van Larebeke 2012). It has been suggested that both the precautionary principle and the principle of physical-chemical hygiene guide regulations covering their use. The devolution of agricultural extension personnel to local government units (LGUs) presents the opportunity for LGUs in the Philippines to provide pesticide-related information to farmers and more closely guide them in crop protection practices. Regulatory officials from LGUs and agricultural technicians from chemical companies can work in partnership, as the latter have influenced farmers' crop protection practices and are expected to undertake activities in relation to product stewardship. Integrated Pest Management (IPM), which combines the use of biological control agents and natural enemies with the safe use of less toxic pesticides, figures prominently in the Farmer Scientists' training Program led by the Ramon Magsaysay awardee, Romulo G. Davide (Calaycay-Cardona 2002).

Modern biotechnology can contribute significantly towards reducing chemical contamination. The planting of *Bt* corn in the Philippines, for example, has reduced the need for insecticide application (Yorobe and Quicoy 2006), as well as the likelihood of mycotoxin contamination resulting from insect damage to the kernels (Wu and others 2004). Sanglatsawai and others (2012) have shown that higher yields from *Bt* corn are to be expected with prospects of reduced losses due to corn borer damage. More recently, *ex ante* impact assessment studies have demonstrated the potential health benefits from *Bt* eggplant through reduced pesticide application (de Guzman 2014). Unfortunately, the utilization of this product has been delayed by a court decision to halt field trials. Animal feed formulation provides the opportunity to enhance nutritional and functional properties of animal products such as eggs (Laudadio and others 2015; Miranda and others 2015). Coconut oil, with its high content of medium chain triglycerides (MCT), added to broiler feed effected a greater reduction in abdominal and subcutaneous fat compared to soybean oil (Wang and others 2015), without compromising lean meat growth. Feeding sows with a diet that contained MCT at 15% resulted in a reduction in newborn mortality and better development of underweight piglets (Zentek and others 2011). These benefits were ascribed to an improved energy supply and stabilized intestinal microbiota, consequently supporting piglet health and performance in the post-weaning period.

On the downside, animal feeds can also be a source of health problems associated with the consumption of animal products. The use of copra meal, a by-product of the coconut oil industry, in feed formulations for aquaculture (Cruz 1997), livestock and poultry, has been plagued with the problem of aflatoxin B1 contamination. The health risks associated with aflatoxin B1 and its detoxification products, e.g. aflatoxin M1 in milk, detract from the benefits that can be obtained from copra meal, e.g. increased lauric acid in muscle and reduced ruminal protozoa in heifers (Jordan and others 2014). This has resulted in diminished demand from importing countries in EU and other importing countries. This problem persists despite the availability of technological solutions (FAO 2004).

Feeds contaminated with the potent carcinogens dioxin and congeners, have compromised the safety of meat and poultry, leading to global events like the dioxin crisis of 1999. The rise in the blood plasma polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran levels in 232 Belgian blood donors in the second half of 2000 was traceable to the1999 dioxin crisis (Debacker and others, 2007), although risk assessment deemed the increase too small to lead to a significant increase in total toxicity.

Although the Codex Alimentarius has adopted the MRLs for the β-adrenergic agonist, ractopa-mine, in bovine and porcine muscle, liver and kidney (CAC 2014), the EU and China objected to the adoption of the MRLs, as neither country allows ractopamine use by local producers. China, in particular, is concerned about allowing higher residues in porcine liver and kidney, which are traditionally consumed in that country. The more potent clenbuterol is not allowed for use on food animals, but illegal use has resulted in cases of acute cardiac toxicity (Salleras and others 1995; Mitchell and Dunnavan 1998).

Availability of agricultural produce through the supply chain

The efficiency of the distribution system is of critical importance in ensuring the availability of harvests to consumers and the retention of nutrients. Stresses resulting from unfavourable conditions in the postharvest environment affect the quality of agricultural produce as it moves through the supply chain. Quality problems in papaya illustrate how the post-harvest system can have a negative impact on the acceptability (del Carmen and others 2012), and, therefore, the utilization of nutrient-dense perishables for and their potential contribution to the management of NCDs. 'Solo' papaya, the predominant cultivar for domestic (principally Manila) and export markets, is sourced from Mindanao, which is free of the papaya ringspot virus. Discussions with growers and traders back in the 90's indicated a strong reluctance to harvesting fully mature papaya as the risk of premature ripening due to inefficiencies in inter-island transport is high (Lizada unpublished). The Ludwig-McGill Human Papillomavirus (HPV) Natural History Study of Brazilian women indicated an association between consuming papaya ≥1 time/week with reduced risk of the persistent oncogenic type of HPV infection, considered a strong intermediate biomarker of cervical cancer risk (Giuliano and others 2003). Aversion to poor-tasting immature papaya leads to missed opportunities for NCD management.

In harvested perishables, i.e. fruits and vegetables, the stress phytohormone, ethylene, accelerates metabolism, leading to premature senescence and the concomitant loss of bioactive compounds like antioxidants. For climacteric produce, the potential for antioxidant activity diminishes as the harvested fruit or vegetable uses up nutrient reserves or reducing equivalents accumulated prior to detachment from the parent plant (Fig. 4). A key nutrient that is lost as a consequence of either senescence or stress is vitamin C, which functions as a defense compound. In papaya the total and reduced glutathione, ascorbic acid and total phenolics showed increases with ripening, but declined with the onset and progress of senescence (Galli and Archbold 2009), when the fruit becomes more oxidized as a whole. Internal browning in the Asian pear, 'KS'13 became evident when its ascorbate level fell below the threshold range of 3.3 to 9.4 mg/100 g fresh weight (Arzani and others 2009). As such, vitamin C serves as a source of reducing equivalents and is oxidized to dehydroascorbic acid (DHA). DHA is either reduced back to ascorbic acid or further degraded to 2,3-diketo-l-gulonie acid and other products, with concomitant loss of functional properties. The Japanese plum, for example, has a functional ascorbate-glutathione cycle to regenerate reduced ascorbate.

Despite this, however, the ascorbate to DHA ratio can still progressively decline during cold storage (Singh and Singh, 2013). Impact damage to tangerines resulted in an initial increase in ascorbate, as a protective response, but eventually progressed to an overall loss in the vitamin (Montero and others 2009).

Postharvest systems are designed to minimize loss in marketability or visual quality, which, fortuitously, reflects the degree to which functional components are retained in the produce. Deterioration in the visual quality of broccoli, i.e. wilting, yellowing and floral abscission, was accompanied by chlorophyll, protein (Page and others 2001) and vitamin C degradation (Izumi and others 1997). Flaccidity consequent to excessive water loss in leafy vegetables occurred concomitantly with losses in vitamin C and protein (Pantastico and Data 1992). Discoloration due to lesions and other overt quality losses reflect the loss in components needed to maintain tissue integrity of the produce. Furthermore, postharvest stress and disease lead to the ethylene-mediated formation of stress metabolites and toxins, e.g. isocoumarins in carrots and ipomeamarone in sweet potato (Haard 1983).

Both overt physical losses and covert changes in labile nutrients would be of greater concern when viewed from the perspective of managing NCDs. Macro- and micro-nutrient losses are incurred as the produce moves through inefficient postharvest systems as exemplified by the handling and transport of Benguet vegetables (Batt and others 2007) and the inter-island transport of banana from Mindanao to Metro Manila (Lizada 1993a). The availability and nutritional quality of these health-promoting commodities are adversely affected by delays, inappropriate handling and packaging, lack of temperature management during transport and storage, and inadequate postharvest facilities and infrastructure.

Postharvest losses include produce contaminated at some point in the supply chain. The safety and quality of meat can be compromised by inappropriate conditions in the abattoir, as well as pre- and post-slaughter conditions. Consumption of food contaminated with physical, chemical or microbial hazards can lead to risks of NCDs either directly, or as part of the long-term sequelae of a food-borne illness. For example, reactive arthritis consequent to bacterial gastroenteritis develops within a month of an enteric infection by *Campylobacter*, *Salmonella*, *Shigella*, and *Yersinia*, and in a few cases by *E. coli* O157:H7 (Garg and others 2008). Besides rheumatoid diseases, other chronic sequelae of food borne illness of microbial origin include renal disease caused by enterohemolytic strains of *E. coli,* and Guillain-Barré syndrome caused by *C. jejuni* (Lindsay 1997).

More than 40% of vegetables sampled from public and private markets in Quezon City and Muntinglupa City was found infested with parasitic organisms (Sia Su and others 2012), pointing to the need for food safety measures to manage parasitic infection from raw vegetable consumption. Food-borne parasitic zoonoses, endemic in some areas of the Philippines, can be traced to the consumption of raw or partly cooked fish, snails, crustaceans and meat (Eduardo 1991). Globalization of food, international travel, and increasing numbers of immune-compromised individuals are among the factors that have increased the risk of food-borne parasitic infections (Orlandi and others 2002). In a number of countries antibacterial chlorine treatment-resistant protozoa, e.g. *Giardia (lamblia) intestinalis*, constitute a dominant public health concern. *G. intestinalis* infection, which has been associated with the consumption of raw sliced vegetables and fruits, can lead to a variety of extra-intestinal and long-term health consequences (Halliez and Buret 2013).

The reduction of postharvest losses has been given international attention since the late 60's with the FAO's War on Waste Program. In 1974 the World Food Conference in Rome drew attention to the significant role that postharvest loss reduction programs can play in increasing food availability (Greeley 1981). Unfortunately, the target set in the 70's of reducing losses by 50% in 10 years was not achieved, as this target was not realistic. Priorities for supporting R & D for policy and development efforts are usually based on data justifying the required investments. Major data gaps on quantitative food loss by individual cause exist, and calls for research in the area as a matter of urgency have been reiterated (Gustavsson and others 2011). Loss figures can conceivably influence policy makers' priorities in terms of public and international investments in postharvest loss reduction (Goletti and Wolff 1999). Traders' loss estimates, as reported by the Special Studies Division of the Department of Agriculture (DA) back in the 60's and 70's, compare well with measured physical losses obtained from experimental loss assessments (Lizada 1990). That postharvest losses are significant and need to be reduced in food and nutrient conservation efforts is no longer debatable, and resources deployed to generate loss data might be better utilized for evaluating interventions.

Utilization

Improved utilization for health through an enhanced appreciation of nutritional value of agricultural products. Enhanced appreciation of the inherent nutritional value of crops or the improved nutrient value of their processed forms can lead to greater demand for and economic value of agricultural products. For example, quinoa, a pseudo-cereal of Andean origin, adaptable to a wide range of agronomic conditions, has been transformed from an underutilized poor man's food to a high value crop that serves as a good source of high-quality protein, vitamins, minerals and other nutrients (Jancurová 2009).

Greater health benefits can be derived from rice when it is consumed as whole grain. Although antinutrients are present in brown rice, the proteinaceous antinutrients in the bran, i.e. trypsin inhibitor, oryzacystatin and haemagglutininlectin, are inactivated during cooking. Phytin, which persists after cooking, can form stable complexes with, and, therefore, interfere with the utilization of iron and other constituents (Juliano 1993). However, by chelating iron, it can suppress iron-catalyzed free radical reactions. Phytin has also been shown to protect the intestinal epithelium from damage by oxygen radicals generated by colonic bacteria (Slavin 2003). Phytic acid, together with other bran constituents, protects the enamel and prevents dental caries (Ventura 1977 as cited by Juliano 1993), a potential benefit associated with the chewiness of brown rice. For individuals who need to restrict their caloric intake, increased chewing activity has been found to reduce energy intake and to modulate gut hormone levels in obese and young men (Li and others 2011). These results are consistent with the observation that slow-paced eating may help curb food intake by increasing fullness and decreasing hunger ratings (Angelopoulos and others 2014), albeit without the added advantage of improving gut hormone responses. The functional character of brown rice, therefore, can be ascribed partly to the physical characteristics of the bran, which diminish the rates at which brown rice disintegrates relative to white rice (Ferruzzi and others 2012). Nutrient release, as reflected in the increase in postprandial glucose, can also be slowed down by the bran serving as a physical barrier.

Health risks are associated with a high intake of polished rice, which has a high glycemic index (GI, i.e. how much a carbohydrate source raises blood glucose relative to glucose or white bread per 50 g available carbohydrate) and a high glycemic load (GL, which is equal to GI X available carbohydrate). In a randomised crossover study, GI in healthy volunteers was 12.1% lower

($p<0.05$) for brown rice com-pared to milled rice, while in diabetics, the value was 35.6% lower (Panlasigui and Thompson 2006). In healthy Japanese women dietary GI and GL based on white rice positively correlated with fasting triacyl-glycerol and fasting glucose (Murakami and others, 2006). In healthy Chinese women a high intake of rice, presumably polished, has been associated with an increased risk of type 2 diabetes (Villegas and others 2007). Even for US men and women whose main staple is not rice, high white rice intake was associated with a higher risk of type 2 diabetes; in contrast, high brown rice intake was associated with a lower risk (Sun and others 2011). An increased consumption of whole grains, in general, was estimated to reduce the risk of type 2 diabetes. More specifically, bran, but not germ intake, was associated with the reduced risk. For gestational diabetes mellitus (GDM) or pregnancy with hyperglycemia a low GI diet was deemed as the most appropriate by a review and meta-analysis of randomized clinical trials (Viana and others 2014). Thus, brown rice might play a role in managing GDM. The underutilization of brown rice can be attributed to a lack of appreciation for its health benefits, although some consumers identify texture and longer cooking time as reasons for preferring polished rice.

An interesting rice product that has not been widely commercialized is fresh *pinipig* or pounded young waxy rice (DA-RFU VII, 2011), distinct from flattened parboiled waxy rice, which is puffed (Juliano 1993). Fresh *pinipig* can contribute 14.0% of the recommended daily dietary fiber intake, and, although it has a lower crude protein, fat, ash, dietary fiber and calcium compared to oats, fresh *pinipig* has a lower phytate content (Faigmane 2002). It also has a distinct bright green color, a unique aroma and chewy texture.

Rice exemplifies a food crop for which the potential contribution of modern biotechnology is not or under-appreciated. In the future, consumer appreciation and acceptance of rice obtained, for example, through conventional breeding of micronutrient (Fe, Zn, Mn)-biofortified rice with golden rice and/or folate-rich rice should significantly contribute as a complementary and cost-effective approach towards addressing micronutrient deficiencies (Bashir and others 2013). Unfortunately, even pro-vitamin A-enriched 'Golden Rice' still awaits regulatory approval after 15 years of its publication. This can be partly attributed to ineffective communication of the benefits to the public (De Steur and others 2015).

Improved utilization and value-adding through primary or secondary processing

Value-adding can also be achieved through partial or extensive postharvest processing. In the marketing and utilization of brown rice, extended soaking of the whole grain in slightly acid water, leads to elevated levels of γ-aminobutyric acid or GABA (Saikusa and others 1994). Anoxia-tolerant rice seeds show elevated GABA levels to counteract the reduced pH consequent to an active fermentative metabolism during germination under water (Magneschi and Perata 2009). GABA rice consumption leads to an improvement of morning blood pressure (Nishimura and others 2014). A number of nutritional and health benefits have been ascribed to GABA rice, including diabetes management (Imam and others 2012). GABA rice has been shown to have chemo-preventive effects on azoxymethane-induced colon cancer in rats (Kawabata and others 1999). Its extracts were found to inhibit the proliferation of human acute lymphoblastic leukemia cells *in vitro*, and stimulate apoptosis in mouse leukemia cells (Oh and Oh 2004). GABA rice is superior to brown rice in terms of cooking and sensory properties (Kaosa-ard and Songsermpong 2012), and is now marketed internationally in various forms (Bulatao and others 2012).

Value-adding has been achieved through lactic acid fermentation, transforming produce into indigenous or traditionally preserved foods with distinct sensory attributes and health benefits, as well. These benefits have been ascribed to probiotics, defined as "live microorganisms, which when consumed in adequate amounts as part of food confer a health benefit on the host" (FAO/WHO 2001). The lactic acid bacteria identified in Philippine fermented foods, such as *burong mustasa, alamang, isda* and *hipon,* include the established probiotics *L. fermentum*, *L. plantarum* and *W. cibaria*, and the potential probiotics, *L. panis* and *L. pontis* (Banaay and others 2013, Dalmacio and others 2011). *Weissella* and *Lactobacillus* have been identified as potential probiotics in *burong mustasa.* The 2001 FAO/WHO consultation agreed that the potential for deriving health benefits from probiotics is supported by adequate scientific evidence. Potential benefits, e.g. improved intestinal health, enhanced immune response, reduced serum cholesterol and cancer risk, point to the potential of managing NCDs through the consumption of probiotics (Kechagia and others 2013). The 2001 FAO/WHO Consultation noted the potential of probiotics in suppressing *Helicobacter pylori,* a type I carcinogen, alone or in combination with antibiotics, the latter leading to fewer side effects and lower risk of recurrent infection.

Prebiotics, which are nondigestible food components (e.g. fiber and resistant starch) selectively enhance the growth and/or activity of beneficial bacterial species already established in the colon (Gibson and Roberfroid 1995). These are fermented in the gut to short-chain fatty acids, such as butyrate, which benefit the probiotic or the host tissue directly (Wollowski and others 2001). Saba banana is a good source of resistant starch, which persists even when the fruit is fully ripe (Lustre and others 1976). Saba starch added to *L. plantarum* has been evaluated and showed good potential for use in combination with a probiotic to produce a synbiotic product (Hongpattarakere and Uraipan 2015).

The use of pro and synbiotics for prophylaxis and therapy presents an alternative to antibiotics in humans and animals (Suskovic and others 2010). Probiotics have been shown to maintain the balance in intestinal microflora in poultry and eliminate pathogens. These effects can lead to enhanced nutrient absorption and performance, as well as reduced bacterial contamination in the carcass (Edens 2003).

Cooking and other thermal processes lead to starch gelatinization and protein denaturation, which facilitate digestion and subsequent absorption. These processes also eliminate microbial contaminants, inactivate antinutrients, degrade inherent chemical hazards, e.g. nitrates, oxalates and cyanogenic glycosides, and transform the food matrix to enhance the bioavailability of beneficial bioactive compounds. Food processing also provides the opportunity to fortify widely consumed products with needed nutrients, extends the availability of food, renders food more palatable and convenient to use, and enhances dietary diversity. The enhanced bioavailability of the antioxidant, lycopene, consequent to thermal processing goes against the popular notion that processing leads to diminished nutritional value (Dewanto and others 2002). Thermal processing has been shown to result in a more efficient uptake of lycopene (Stahl and Sies 1992). This has been attributed mainly to its release from the food matrix (Gartner and others 1997) and not isomerisation (Ross and others 2011).

The health and nutritional benefits that can be derived from *Moringa oleifera* have been studied and reviewed (NAP, 2006). However, leaf nutrient bioavailability has not been compared systematically among different preparations, e.g. fresh-blanched, boiled, fried or dried and/or powdered.

For meat, cooking temperature and duration are factors that need to be controlled to minimize the formation of the carcinogens, heterocyclic amines and polyaromatic hydrocarbons. An epidemiological study involving 193 subjects with pancreatic cancer and 674 controls showed an association between these carcinogens and increased risk for pancreatic cancer (Anderson and others 2005).

Besides adding value to agricultural produce, the US food processing industry and restaurants can play a pivotal role in reducing sodium intake (IOM 2010), since dietary salt is derived largely from processed and restaurant foods. With globalization and the consequent westernization of Filipino food habits, processed foods are conceivably the main dietary source of sodium for Filipinos as well. It is anticipated that the sensory preference for salty food is likely to decline if salt levels in processed and restaurant food decline. The recommended strategies for reducing salt intake in the US combine measures that are mandatory (mandatory standards) and voluntary, e.g. the "stealth" approach for processed food Bliss 2012).

Intended use

"Intended use" is a basic consideration in determining whether the consumption of a specific food or food product provides health benefits, and in assessing food-borne health risks. In fact, from a regulatory perspective, the status of a food is primarily determined by its intended use. Grapefruit eaten before meals has been associated with significant weight loss and improved insulin resistance (Fujioka and others 2006). However, furanocoumarins present in grapefruit are metabolized by CyP3A4 in the small intestines, causing irreversible inactivation of this enzyme, which also metabolizes a wide range of orally administered drugs. The grapefruit-drug interaction has been attributed to this inactivation (Bailey and others 2012). Some varieties of pummelo have been found to have levels of furanocoumrins that can effect the same inactivation (Guo and Yamazoe 2004). Pummelo cultivars low in furanocoumarins can be used to produce grapefruit hybrids with no or low furanocoumarins (Chen and others 2011).

The disulfiram-ethanol-like interaction elicited when alcohol is consumed with durian, provides yet another example of the need to consume foods, including those with a long history of use as food, according to its intended use (Maninang and others 2009; Maninang and others 2012).

Need for evidence-based dietary recommendations

In 2012 the Israel Heart and the Israel Dietetic Associations published a position paper on the role of lifestyle factors, including nutrition in the etiology of CVD. The position paper evaluated the level of evidence that defined the strength of dietary recommendations in relation to CVD and related risks (Eilat Adar and others 2013). In the case of nutrition recommendations in relation to cancer survivorship, a review of the current evidence-based dietary guidelines showed that evidence supporting such recommendations is still lacking (Robien and others 2011). Besides the need for evidence-based dietary recommendations, the quality of the underlying evidence used must be evaluated to gauge the strength of such recommendations. In an effort to provide guidance in the assessment of the quality of evidence and the strength of recommendations, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system, which takes into account uncertainties in addition to quality of evidence, was developed and has been adopted by organisations worldwide (Guyatt and others 2008).

The lack of a strong basis for dietary recommendations has led to misleading diet-related information. For example, prior to the 80's when the antioxidant activity of lycopene was established, the pigment was largely ignored (American Cancer Society 2010). Interestingly, in the 60's a popular weight loss program advised dieters not to eat ketchup, and considered watermelon, a good source of available lycopene, a forbidden fruit (McKinnon 2013). Reviewing literature, Shin and others (2013) found no association between egg consumption and CVD risk, but cautioned that the results of their meta-analysis might not justify changes in the existing dietary advice, noting the possible association between egg consumption and increased incidence of type 2 diabetes in the general population, and increased CVD comorbidity in diabetic patients. This meta-analysis was cited in the U.S. Scientific Report of the 2015 Dietary Guidelines Advisory Committee, which, despite the authors' caution and recommendation for more studies, included egg in the meat group. In a more recent review Fuller and others emphasized the need to focus on an individual's entire dietary intake rather than on specific foods or nutrients in dietary guidelines.

Dietary recommendations on coconut oil

The above inclusion of eggs contrasts with the recommendation on coconut oil. For years, recommendations on dietary fats have discriminated against coconut oil, pointing to the predominantly saturated fatty acid profile, without taking chain length in to account. The Scientific Report of the 2015 Dietary Guidelines Advisory Committee submitted to the US Departments of Agriculture and Health and Human Services grouped tropical oils, e.g. coconut oil, under "empty calories", stating that these contribute to saturated fat (SF) intake and, therefore, advised that their consumption should be limited.

St-Onge and colleagues (2008) have pointed to the need to make a distinction when the cardiovascular health effects of SFs are considered, since medium chain SFs do not apparently cause the adverse health effects attributed to long chain fatty acids. They pointed out that disparate findings on the health benefits of coconut oil, particularly on cardiovascular health, might be attributed to differences in materials and methods used by different laboratories. Studies demonstrating the favourable physiological effects of MCT in relation to obesity covered by the 2002 review by St-Onge and Jones used MCT oil with no laurate (12:0).. Unfortunately, these studies neither involved comparisons with coconut oil without any other fat mixed with it, nor triglycerides with lauric acid as a major component. St-Onge, herself, who has studied the effects of medium chain fatty acids (MCFAs) for years, has used MCT oil (St-Onge and Jones 2003), supplied by the Stepan Company. This company produces MCT oil ranging from 3–30% capric acid (6:0) and, 97–68% caprylic acid (8:0) (Hugh and others 2010). MCT oil, a by-product of fractionation of coconut oil, is stripped of the lauric acid (12:0) component, which is valued more for its industrial use, as in the manufacture of cosmetic products, soaps and detergents.

It is interesting to note that the 2002 review by St-Onge and Jones referred to lauric acid as belonging to the group of MCFAs, and considered only triglycerides of fatty acids with a chain length >12 as long chain triglycerides. The reference to lauric acid as a MCFA is consistent with the earlier observation that individual fatty acids undergo differential oxidation in humans, with lauric acid oxidized at twice the rate at which LCFAs, including myristic acid (14:0), were oxidized. DeLany and others (2000), thus, concluded that lauric acid behaves as a MCFA. In 2008 St-Onge and others went farther to point out that MCFAs are found in greatest concentrations in coconut oil.

The design of more recent studies specifically includes lauric acid or coconut oil as a source of MCFA. Using hydrogenated coconut oil (HCO; with lauric constituting 36.7 % of MCFA), for example, Turner and others (2009) observed that mice given the HCO diet do not develop insulin resistance in either muscle or adipose tissue. HCO-fed mice showed less muscle triacylglycerol (TAG) accumulation than lard-fed mice (41% increase with HCO vs. 295% increase with lard). The lack of lipid accumulation in the muscle was attributed to the observed increase in mitochondrial oxidative capacity in this tissue of HCO-fed mice. Apparently, the effect on TAG is tissue specific. The 2009 report of Turner and others noted that the liver showed higher lipid accumulation in the HCO-fed mice. Adverse effects, i.e. increased plasma LDL cholesterol and TAG, reported in a study using MCT-rich oils (Tholstrup and others 2004) and noted in a review on the cardiovascular effects of virgin coconut oil (Sy and Olix 2007) might be due to the total fat intake involved. Moderating the amount of MCT consumed, particularly if combined with an exercise regime, (1) led to improved lipid profiles and (2) prevented the adverse effects on biomarkers of CVD risk, i.e. decreased HDL cholesterol, and increases in total cholesterol, LDL cholesterol and triacylglycerol, associated with MCT intake (Hugh and others, 2010). Presumably, moderating the MCT intake level would preclude the increase in hepatic lipogenic enzymes.

The group pointed to the potential for MCFA, along with short chain fatty acids, to be incorporated into reduced-energy lipid products designed to enhance the thermic and satiety effects of food, accelerating fat oxidation, and thereby functioning as aids to manage weight and improve cardiovascular health. They recommend the conduct of free-living clinical studies to evaluate the health effects of MCT consumption, including natural MCT-rich oils, specifically coconut oil. It is interesting to note that the uncoupling protein3 (UCP3) content in skeletal muscle of HCO- vs.lard-fed mice showed an 88% and 40% increase, respectively (Montgomery and others 2013). UCP3 acts as a mild mitochondrial uncoupler, resulting in an attenuation of oxidative damage, and might be associated with the thermic effects of coconut oil.

Coconut oil is not subject to oxidation and does not generate hydroperoxides, a distinct advantage when used in deep frying (Choe and Min 2007). Interestingly, for dermatological conditions, virgin coconut oil has been regarded as neutral or anti-inflammatory due to its predominantly saturated fatty acid content, helping balance the pro-inflammatory effects of polyunsaturated fatty acids (PUFAs) (Verallo Rowell 2007). Moreover, no *trans* fats are formed in the complete hydrogenation of coconut oil, which leads to the full hydrogenation of the small amounts of oleic (18:1) and linoleic (18:2) acids.

Dietary recommendations on polyunsaturated oils

A review of studies on the association of dietary saturated vs. polyunsaturated fats with coronary risk led to the conclusion that there is no clear support for guidelines encouraging high consumption of polyunsaturated fats and reduced consumption of saturated fats (Chowdhury and others 2014). Replacing saturated with polyunsaturated fats, specifically, *n*-6, may be misguided, as increased consumption of polyunsaturated fats may lead to increased coronary risks and overall mortality (DiNicolantonio 2014).

PUFAs are susceptible to autoxidation, which proceeds via a free radical mechanism involving active oxygen species (Lizada and Yang 1981). When used for frying (150 °C to 190 °C), oils with high PUFA content undergo oxidation through essentially the same mechanism as autoxidation (Choe and Min 2007), forming hydroperoxides that break down into a number of oxidative products. Alkenals, which constitute a group of PUFA oxidation end products, ranged from 119- 33 nmol/mL in fresh vegetable oils, the latter increasing by 2.9–11.2 times after heating for 25 minutes at 225°C (Halvorsen and Blomhoff 2011). The highest concentration of alkenals was detected in sunflower, corn and soybean oils, with one sunflower sample having 538 nmol alkenals/mL.

Feeding mice for 6-weeks with a diet containing mildly oxidized *n*-3 PUFA (50 °C in the dark) led to an accumulation of plasma 4-hydroxy-2-hexenal (4-HHE), an alkenal, indicating its absorption in the small intestine (Awada and others 2012). The accumulation of 4-HHE was accompanied by an increase in inflammatory markers in plasma (e.g. gastrointestinal glutathione peroxidise), endoplasmic reticulum stress in the upper small intestine, and reduced Paneth cell number in the duodenum. The authors recommend the protection of *n*-3 PUFA rich foods against oxidation during processing, storage, and/or final handling, particularly if they are to be consumed by patients advised to increase their *n*-3 PUFA intake to manage acute or chronic diseases. It would be interesting to find out if the observed inflammation-related effects are more pronounced after a long-term ingestion of food fried in *n*-3 PUFA rich oils. Subjecting PUFAs to partial hydrogenation enhances stability against peroxidation but gives rise to *trans*- fatty acids, all of which may raise the ratio of LDL to HDL cholesterol irrespective of origin or structure (Brouwer and others 2010).

Dietary recommendations without robust evidentiary support, as illustrated by previous or current recommendations on the consumption of saturated fats from coconut oil or eggs have led to confusion among consumers and even among clinicians. Debates on the extent that salt intake should be reduced and whether limiting sodium intakes to <2500 mg/d will lead to improved health (Alderman 2014) continue. WHO recommends sodium intake of < 2000 mg/day (<5 g/day), which should lead to a desirable 1:1 molar ratio of K:Na if the potassium intake is 90 mmol/day. A significant blood pressure reduction by increased potassium intake was observed at a sodium intake of 2000 – 4000mg/day. Most populations stand to benefit from increased potassium intake as the sodium intake for most populations is >4 g/day (Aburto and others 2013). This observation provides a good example of the requirement for nutrient balance and the need to look at interactions among nutrients. Dietary prudence dictates moderating salt intake, consuming more plant-based foods and taking advantage of the enhanced gustatory attributes of food with the use of herbs that have been shown to have beneficial bioactive components, as well (Opara and Chohan 2014; Craig 1999).

A clearinghouse for diet-related information and recommendations that evaluates and objectively treats information as they become available is needed.

Need for multi-sectoral, multi-disciplinary approaches

Enhancing utilization of agricultural products for health calls for innovative strategies in nutrition education, formulating nutritious recipes and meal plans, mobilizing multidisciplinary extension teams, and effective communication among health, nutrition, home economics and agricultural extension specialists (FAO 2013b). A new paradigm is needed to ensure that the competence best provided by home economists is effectively deployed in the management of NCDs. Food scientists need to interface with nutritionists, not only in terms of food composition and formulation, but also in terms of the sensory properties of food, which determine palatability and fuller utilization for health (Freedman 2012). Oral stimulation has been found to play a role in food intake effect on appetite-regulating hormones (Spetter and others 2014).

Access

Household income, if appropriately utilized, is key to ensuring access to food for health. The following recommendations were among those noted in the 2012 FAO consultation on Programming Agriculture for Nutrition:

1. increasing women's control of income would likely have favourable effects on expenditures for nutrition;
2. regular, even if small, income may be more beneficial than larger, less frequent payments; and
3. provision of nutrition education or income in-kind leads to increased likelihood of income being spent on food.

Except for income in-kind, the above recommendations are consistent with the features of the Conditional Cash Transfer Program or *Pantawid Pamilyang Pilipino* Program (4Ps; DSWD 2009). Among the four specific objectives of this program is raised consumption of nutrient dense foods among poor households. Relative to non-beneficiaries, food spending per person per month in 2011 was found to increase among 4Ps households; however, the increase was highest on carbohydrates (rice and corn), followed by high-protein food (e.g. eggs fish and dairy), and lowest on fruits and vegetables (Tutor 2014). For these households a mere 7.7% of total food expenditure was spent for fruits and vegetables.

Income in-kind is featured in US Domestic Food Assistance programs, from which additional insights may be gained (Aussenberg and Colello 2015; Herman and others 2008):

1. Senior Farmers' Market Nutrition Program, offering vouchers/coupons to low-income seniors for fresh produce in farmers' markets, roadside stands, and/or other approved venues; and
2. Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), providing vouchers for supplemental foods for low income pregnant, and postpartum women, infants and children ($\leq$ 5 years of age) who are at nutritional risk from participating stores, all of which are required to make available a minimum number of fruits and vegetables.

While the first clearly links and benefits both beneficiaries (low-income seniors) and producers, a farm-to-WIC scheme has been considered in the state of California (Kaiser and others 2012). Such an approach might be built in to the 4Ps, to improve access to, while benefiting farming households producing fruits and vegetables. A voucher-based program for senior citizens might also be considered, sourcing fruits and vegetables from the same outlets patronized by 4Ps beneficiaries, e.g. producers' markets. The rationale behind the focus on fruits and vegetables is that low-income households face economic barriers to accessing and consuming fruits and vegetables (Kaiser and others 2012). Inadequate fruit and vegetable consumption has been observed in Southeast Asia, despite the fact that many areas have not been urbanized (Dans and others 2011). Households that are 4Ps beneficiaries in the Philippines apparently face the same economic constraint, in spite of the cash subsidy provided. Undoubtedly the inefficient postharvest system for fruits and vegetables adversely affect the supply, and the cost of actual, or even anticipated physical loss (shrinkage or *reseco*) is built into the price of these commodities.

Additional insights may be gained from the "Graduation Program", which initially targeted the very poor in six countries and has been replicated in 20 countries. The program included components similar to conditional cash transfer programs, but featured a core component of a one-time transfer of a productive asset consisting mostly of food animals, which were chosen by the beneficiaries and for which they were given training (Banerjee and others 2015).

The above programs demonstrate that economic access, and, therefore, food security can be improved significantly by agriculture-linked approaches, which provide income opportunities for both farming and urban households. Programs for reducing food insecurity lead to mutual benefits for agriculture and health. Data from poor 18 to 65 yr old adults in the US NHANES (1999 - 2004).show an association between food insecurity and NCDs, particularly diabetes, among the most food insecure (Seligman and others 2010). The investigators hypothesized that food insecurity, being a highly stressful state, both emotionally and physiologically, leads to elevated cortisol, which is frequently associated with visceral adiposity. Based on a cross-sectional survey and chart review of diabetic patients in safety net health clinics in San Francisco, it was shown that food insecurity due to poverty contributes to poor glycemic control among patients with type 2 diabetes (Seligman and others 2011).

Ensuring economic access for tobacco farmers

Measures to reduce smoking are expected to significantly affect tobacco farmers' income. Substitute crops for tobacco need to generate as much or greater income for these farmers. In a survey of the tobacco growing areas in the Philippines, vegetables such as onion and tomato were found suitable for Region I (Espino and others 2009). As of 2009, a little less than a third of the farmers in Ilocos Norte and Ilocos have grown tomato with the operation of the National Foods Corporation Processing Plant in Sarrat. Other than selling harvests to the processing plants for tomato paste production, farming households have engaged in processing tomatoes into vinegar or candy (Mangabat 2009). At some point, the farmers were also producing high quality sun-dried tomato, as the environmental conditions at harvest time are ideal for the production of this high value crop. Unfortunately these products have not been widely marketed and their production has not been sustained. Given the range of uses of processed tomato, market opportunities abound for these and other products, e.g. jam spreads, salsa and relish, and should provide an incentive for tobacco growers to switch to tomatoes and other crops.

Urban horticulture: market gardening for urban dwellers

A FNRI case study highlighted the contribution of urban gardens to urban food security. The study pointed to the need for local ordinances permitting the use of vacant lots for community vegetable gardens, and technical support consisting of inputs and extension services (Pedro and others 2004). This recommendation calls for a partnership between the Departments of Agriculture and Environment and Natural Resources, which currently implement programs on urban gardening, and LGUs. Communities and homeowners'/condominium associations need expert advice if they are to incorporate edible species in landscapes. More specifically, a public-private sector partnership might be explored in allocating areas and support for therapeutic horticulture, which provides not only for the enhanced availability of plant-based food, but physical activity as well.

Stability

For this dimension, farming households, besides the dynamic interaction between farmers or farming communities and the environment, need to be given due attention. Poverty statistics for 2000, 2003 and 2006 show that farmers and fishermen are plagued by insufficient income and, thus, constitute two of the poorest sectors (Virola and Balamban 2015). In 2014 the Department of Budget and Management (DBM) acknowledged that Filipinos depending on farms and fisheries for livelihood are among the poorest in our country (DBM 2015). Projects that promote inclusive growth will ensure that farmers and fisherfolk will be able to participate in our thrust to maximize the country's agri-business potential." Farmers and fisherfolk are most affected by the poverty loop (Dans and others 2011), whether they stay in rural areas or migrate to urbanized areas. Farmers play a critical role in food security, and should, therefore, be major beneficiaries of food security programs. In fact the predominant focus of the FAO's 2013 guidance on agriculture programming for nutrition is the improvement of the nutritional status of producers, who are also consumers. This focus on producers considers approaches to address the dual burden of under- and over-nutrition through nutritious and sustainable diets.

Functional farmers' organizations are vital to programs mainstreaming smallholders in the value chain and sustaining increased incomes. This was demonstrated in the "White Revolution" in India that dramatically transformed this country from one relying almost completely on powdered milk imports to the world's largest milk producer (FAO 2003). Among the recommendations emanating from a series of consultations convened by the National Academy of Science and Technology of the Philippines (NAST PHL) is the professional management and institutional support for farmers' organizations (NAST PHL 2012). The roadmap to an effective response to this recommendation will require a holistic approach to the transformation of these cooperatives to business entities. Complementing this is the full implementation of agrarian reform involving all three branches of government. Dedicated extension units in state universities and colleges of agriculture might be strengthened with a networking mechanism for these units to share and exchange information on best practices. Furthermore, the research development extension continuum needs to ensure the transdisciplinary translation of research results into interventions that are evaluated and refined using farms or farming communities/organizations as laboratories. Smallholder coconut farmers, for example, should benefit from effective action on the foregoing recommendation, more specifically, in relation to coconut drying and copra marketing, which might be better undertaken by a professionally managed central facility serving a farmers' organization. Better quality copra can be reliably produced in larger volumes, leading to a better bargaining position for producers. This translates to improved milling recovery and reduced aflatoxins in copra meal for feeds (Lizada 2008).

The dimension of stability depends on whether agricultural production is sustained or is resilient, capable of coping with the vagaries of climate and other environmental changes. Resiliency of agriculture, overall, depends not only on technological interventions, but also on appropriate policies and good governance. Only with these elements will agriculture be sufficiently attractive to succeeding generations of farming families. The research development extension (RDE) continuum builds on available scientific information linking agriculture to health via nutrition. Prior to the formulation evidence-based recommendations for which randomized clinical trials serve as the gold standard, available information obtained through epidemiological and observational studies can be utilized to provide opportunities for agriculture to contribute to NCD management. At the very least, ensuring the availability of a wide range of farm outputs provides the flexibility needed for diet modification. Evidence-based recommendations should ultimately guide agriculture in production programming, cultural management and distribution in responding to nutritional requirements for health.

The food security dimension of stability figures prominently in the UN document "Transforming our world: the 2030 Agenda for Sustainable Development" (UN 2015), which builds on the Millenium Development Goals by shifting to Sustainable Development Goals (SDG). The health-related SDGs illustrate the intertwined relationship between health and agriculture. Noteworthy is the launching of a Technology Facilitation Mechanism to mobilize the UN system on science, technology and innovation-related matters, to enhance synergy and efficiency through multi-stakeholder participation in meeting the SDGs.

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