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## **INNOVATIONS IN VEGETABLE FOOD SYSTEMS FOR FOOD SAFETY AND NUTRITION SECURITY IN LOWER AND MIDDLE INCOME COUNTRIES IN ASIA**

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### **ABSTRACT**

*Globally, one person in three is malnourished. The coexistence of undernutrition with overweight and obesity, and micronutrient deficiencies clearly indicates that current food systems are failing people's health. More than half of the world's malnourished children live in Asia and the Pacific. The trend is a homogenization of diets with processed and unhealthy foods that are rich in salt, sugar and saturated fats but poor in essential vitamins and minerals. One of the greatest challenges is to convince consumers to change their dietary habits to eating healthier foods such as fruit and vegetables. But when the demand exists, the challenges of supply and food safety still remain. To improve food safety and nutrition security, innovations that simultaneously increase the supply and demand for vegetables are needed. Only a food system approach will help ensure that safe and nutritious vegetables are not only available but also accessible, affordable and consumed. According to the High Level Panel of Experts on Food Security and Nutrition of the United Nations Committee on World Food Security (HLPE, 2017), food systems can be seen as made up of three fundamental elements: food supply chains, food environments, and consumer food behavior. Using this framework, the authors discuss the challenges, the innovations and changes needed to enhance safe vegetable production and consumption in lower and middle income countries in Asia. The World Vegetable Center, an international non-profit research organization, continuously innovates smart technologies to support and expand the production and consumption of safe nutritious vegetables in LMICs in Asia and other regions of the world. In the current context of global malnutrition, the importance of investing in vegetable research and innovations, is more relevant than ever.*

**Keywords:** food systems, food safety, nutrition security, malnutrition, vegetable, Asia

## INTRODUCTION

Malnutrition poses a formidable challenge to the world at large. One of every three people is suffering from some form of malnutrition (FAO, 2018), be it undernutrition, overweight or obesity, or micronutrient deficiency. An estimated 88% of countries worldwide are simultaneously faced with at least two forms of malnutrition and 29% face all three forms. The future of a country obviously depends on the health of its people and economic costs related to poor health are staggering: US\$ 3.5 trillion annually (Development Initiatives, 2018).

This ‘triple burden’ of malnutrition clearly indicates that current food systems are failing people’s health. They also jeopardize our planet’s health. The recently published EAT-Lancet Commission report (Willett *et al.*, 2019) calls for urgent action to provide a growing global population with healthy diets from sustainable food systems. Nelson *et al.* (2018) argue that the greatest food security challenge by 2050 will be related to providing nutritious diets rather than adequate calories. They state that ‘research priorities and policies should emphasize nutritional quality by increasing availability and affordability of nutrient-dense foods and improving dietary diversity’. These nutrient-dense foods such as vegetables, fruit and nuts are seen as a new generation of ‘staple’ foods.

According to the High Level Panel of Experts on Food Security and Nutrition of the United Nations Committee on World Food Security (HLPE, 2017), which is the foremost inclusive and evidence-based international and intergovernmental platform for food security and nutrition at the global level, a food system ‘gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes’. Food systems can be seen as made up of three fundamental elements: food supply chains, food environments and consumer behavior. The interplay and dynamics of these three elements determines dietary and economic, political and environmental outcomes.

Vegetables of global (e.g., tomato, peppers, cucurbits, brassicas, alliums, legumes) and traditional (e.g., bitter melon, *kangkong*, okra, nightshade, amaranth) types are efficient sources of several important micronutrients such as  $\beta$ -carotene (precursor of Vitamin A), folate, iron, calcium, zinc, dietary fiber and functional phytochemicals. Nevertheless, vegetable consumption in many Asian low and middle income countries (LMICs) is far below the WHO/FAO recommended amount of 200 g per person per day.

Creating demand for nutrient-dense foods such as vegetables requires work on *awareness*, *acceptability* and *desirability* of those products. Consumers have personal preferences and food habits, they may be concerned about food safety or simply not be aware of the importance of eating regular servings of fruit and vegetables. Consumer food behavior is a vast area of work that has been much researched by the private sector. It urgently needs to be adapted to shift consumption patterns toward healthier food choices. Changes in the food environment must make vegetables more *accessible* and *affordable* to consumers with different purchasing powers. The places where food is purchased and directly consumed should provide healthier and affordable meal options. Changes in vegetable supply chains must aim at increasing the *availability*, *affordability* and *accessibility* of safely produced nutrient-dense vegetables. Changes are needed in the entire food system to simultaneously support supply-side opportunities and demand-side motives for healthier food choices.

Asia continues to experience rapid urbanization. Projections show that urban populations in Asia will have 1 more billion people by 2050, with 63% of the total Asian population living in cities. Tschirley (2017) showed that diets in LMICs because of urbanization are transforming in three ways: food is becoming more purchased, food is becoming more perishable with increasing consumption of meat, dairy and fresh produce (especially fruit and vegetables), and food is becoming more processed. Urbanization is leading on the one hand to growing problems of over-nutrition and obesity but also to a rising demand for quality and nutritious food, in smaller and bigger cities alike. Meanwhile the great majority of very poor and undernourished people are living in rural areas. This poses a major challenge, but also an opportunity: how to connect cities and smallholder farmers, and tap into this rising urban demand, thereby making food safe, nutritious and affordable while reducing poverty on-farm in the rural and peri-urban areas? The challenge is to create a triple-win of favorable dietary, economic and environmental outcomes: greater diversity of safe and affordable nutritious food, employment and income for farmers, and safe and environmentally friendly production practices.

In this paper, we will zoom into opportunities and innovations in vegetable food systems to

contribute to food safety and nutrition security in LMICs in Asia. Food systems in Asia comprise of all three broad types of food systems defined by HLPE (2017): traditional food systems, mixed food systems and modern food systems. The paper will focus on *mixed food systems* where food producers rely on both formal and informal markets to sell their crops. In these mixed food systems, highly-processed and packaged foods are generally more accessible and affordable than healthier food. Most consumers have limited or no access to food-based dietary guidelines. Food safety and quality standards may exist but are not always followed by producers (HLPE, 2017).

The objectives of this paper are to (i) discuss innovations and policy interventions that have the potential to enhance safe vegetable production and consumption using the HLPE framework; and (ii) discuss the challenge of addressing enhanced supply and demand for safe and nutritious diets *simultaneously* to achieve positive dietary, economic and environmental outcomes.

The discussion includes innovations and policy interventions across the entire food systems spectrum, from Consumer food behavior (Section 1) to Food environments (Section 2) to Vegetable supply chains (Section 3). A review of food safety concerns in LMICs in Asia is provided under the supply chain section as health outcomes of nutritious food are heavily influenced by food safety concerns. Section 4 describes the challenge of addressing supply-side opportunities and demand-side motives for healthier diets *simultaneously*. For example, focusing only on supply-side opportunities by improving the availability of nutrient-dense vegetables may not result in improved dietary outcomes because of accessibility or affordability issues of such vegetables for consumers. The paper concludes with recommendations for public policy and decision-makers to further plan and invest in innovations, research and interventions to improve food safety and nutrition security using a food system approach.

## CONSUMER FOOD BEHAVIOR

Consumer food behavior reflects ‘the choices made by consumers, at household or individual levels on what food to acquire, store, prepare and eat, and on the allocation of food within the household’ (HLPE, 2017). Decision-making depends on income levels, personal preferences and taste, cultural settings and the food environments people have access to in terms of food variety and prices. Innovations in this area of food systems aim to nudge consumers towards eating healthier foods, i.e. to enhance the acceptability and desirability of micronutrient-dense food such as vegetables.

Unlike staple grains and roots and tubers, fruit and vegetables are not consumed ‘automatically’. In LMICs, consumers will prioritize food that provides calories while vegetables are often considered as less essential and expensive. Rising vegetable production and rising incomes are no guarantee for an increase in vegetable consumption; in some countries, vegetable consumption has even declined with rising average incomes (Global Panel, 2016). This may be related to a lack of awareness about the importance of fruit and vegetables for good health, or simply because people are submerged with unhealthy food options. In urban environments in Asia and elsewhere, billboards urging people to eat unhealthy food such as highly processed bakery products, instant noodles, and sweetened beverages are a common sight. There may be many other reasons why vegetables are not included in family meals related to taste, changing lifestyles, convenience, food habits, and food safety concerns (Schreinemachers *et al.*, 2017). Below we discuss innovations to nudge consumer behavior towards healthier diets.

## **Innovations to enhance awareness, acceptability and desirability**

Whatever efforts are made, it is households and communities that remain on the front lines in combating malnutrition and making the decisions for themselves. Presenting nutritious foods in a different manner, such as through attractive packaging and labeling, may nudge consumers towards healthier food. Children often do not appreciate vegetables at first bite. It is important to provide them food choices with healthy options, such as balanced meals with plenty of diverse cooked vegetables and salads to choose from. Other nudges can be used such as cartoon characters (think of Popeye the Sailor man deriving super strength from eating spinach) or smiley stamp cards as motivation incentives. The choice of unhealthy food options should be severely restricted inside schools, for instance, by banning vending machines selling high sugar drinks. Changing consumer behavior through social media may well become the most important pathway for people (in particular young people) to choose healthier food options. Several examples exist of the use of smart phones to guide decision-making for purchasing healthy food (Gilliland *et al.*, 2015). This type of innovation has the potential to reach millions of people in a relatively short time but is relatively untested until now and would depend on a viable business model. Demonstrations of recipes that are based on nutritious food ingredients in villages have shown potential in Africa. In urban settings, cooking shows on TV, are effective behavioral change communication tools, in particular if they involve celebrity cooks or cooking contests.

Targeted information campaigns and nutrition counseling may help nudge consumers towards healthier food choices. For example, Ochieng *et al.* (2017) found a significant increase in the dietary diversity of children under the age of 5 and of women in reproductive age among rural and urban households as a result of a campaign promoting the use of nutrient-dense African traditional vegetables in Tanzania. There is a huge effort needed in nutrition campaigns advocating for increased fruit and vegetable consumption. Banning advertisement for unhealthy food is an example of a hard policy measure that may have substantial benefits. For example, the Chilean government, facing increasing rates of obesity, has decided to implement marketing restrictions, mandatory packaging redesigns and labeling rules to transform consumer behavior. Since the food law was enacted in 2016, it has forced private companies to remove iconic cartoon characters from sugary cereal boxes, it prohibited the sale of junk food in schools, and banned advertisement of such products during children television programs. These measures are considered as one of the world's most ambitious attempts to transform food consumption patterns.

## **Innovations to enhance affordability**

Financial incentives have also been used to stimulate healthier eating. This may include insurance rebates or reduction of the price of nutritious food through subsidies or taxes on unhealthy foods and sugary drinks. For example, vouchers were the most effective in encouraging vegetable consumption in a study comparing the impact of provision of food, cash or vouchers among low-income populations in Ecuador (Hidrobo *et al.*, 2014). Similar positive results were obtained in the US (Bartlett *et al.*, 2014) when providing economic incentives to stimulate fruit and vegetable purchases. More recently, Lee *et al.* (2019) used a validated simulation model to estimate the health and economic impact of two policy scenarios in the US: a 30% subsidy on fruit and vegetables (scenario 1) and a 30% subsidy on a healthy food basket, including fruit and vegetables (scenario 2). Both incentives were highly effective in preventing cardiovascular disease (CVD) events and CVD related deaths and would save between US\$ 40 billion (scenario 1) and US\$ 100 billion (scenario 2) in healthcare costs.

## **1. FOOD ENVIRONMENT**

The food environment can be thought of the settings in which people access, purchase and eat food. This includes home gardens, informal wet markets and supermarkets, food stalls, but also public and private-sector institutions that serve meals to large numbers of people, such as schools, restaurants, hospitals, airports and canteens of private companies or public institutions. Food environments determine what food consumers can access at a given time, at what price and with what degree of convenience. Food environments can therefore both constrain and prompt food choices and are the link between food supply chains and people's diets (Lartey *et al.*, 2016). Innovations in the food environment need to increase the accessibility and affordability of nutritious food, like fruit and

vegetables. Many urban food environments in Asian LMICs provide very little options for consumers to purchase nutritious food such as fruit and vegetables and highly processed, fast food is the norm.

### **Innovations to enhance affordability and accessibility**

Promoting shorter value chains and stimulating greater connectivity between farm and plate may convince consumers to eat more vegetables. Many consumers are worried about food safety issues and once they understand how and where vegetables are produced they may become more likely to purchase and consume vegetables. Urban consumers even in LMICs will often be willing to pay more if they are convinced about food safety standards. Such innovations may include door-to-door delivery of safely produced vegetables or delivery through Uber-type of innovations, with vegetables ordered on-line and delivered to your doorstep. Urban consumers eating outdoors may also be swayed to eat nutritious food if presented in an attractive manner. This may range from eating vegetable snacks from hip mobile carts to healthy dishes in restaurant settings. Promising examples exist around the world, where clients are purchasing weekly baskets of organically grown vegetables from local producers but these initiatives remain largely experimental or at a relatively small scale.

School garden programs (hands-on experience with gardening combined with health and nutrition education) have been tested in middle and high-income countries to increase the diet diversity of children. Schreinemachers *et al.* (2017a, 2017b) evaluated the impact of such school garden programs in LMIC countries in Asia and Africa. They observed a significant increase in children's awareness, knowledge and preference to consume fruit and vegetables. However, there was no commensurate increase in fruit and vegetable consumption. Similar results were reported in high-income countries (Ohly *et al.*, 2016). Results point at the need to work on supply systems for the schools either through the private sector or through stronger community involvement.

Home garden interventions are particularly effective to enhance nutrition security at the household level in rural settings. They combine hands-on training in vegetable cultivation with nutrition-messaging and health behavioral change communication (World Vegetable Center, 2016). Home garden interventions often target women as they generally decide on food choices at household level. The approach makes vegetables available, affordable, accessible, and acceptable to poor rural households.

## **2. VEGETABLE SUPPLY CHAINS**

Vegetable supply chains need to ensure adequate year-round availability of safely produced vegetables at affordable prices. This may be influenced by policy and regulatory measures in the food environment. Practices along the value chain from production to marketing must safeguard nutritional value and protect food safety. Local production will stimulate employment and income generation, and will reduce the 'length of value chains'. There is a high potential to reduce food safety and environmental concerns.

### **Food safety - overview**

Food safety of marketed vegetables encompasses issues around hygiene, nitrite derived from fertilizer application, pesticide residues, and natural contaminants such as pathogenic microorganisms, mycotoxins and heavy metals. Among them, pesticide residues, especially organochlorine and organophosphate compounds, in vegetable produces is a major challenging problem in Asia.

Over the last few years, it has been recognized that vegetable safety hazards may arise at different stages of the vegetable value chain from production up until consumption. To ensure the food safety of marketed vegetables, the hazards associated with different stages namely input materials, farming practices and food processing activities need to be prevented from entering the chain or reduced to acceptable levels at each and every stage. This requires the commitment of all players in the vegetable value chain, involving producers, traders, processors, distributors, government as well as consumers who share responsibility for ensuring food safety as well as quality.

The World Vegetable Center conducted a systematic review of scientific literature published between 2004 and 2019 and accessible from the Internet on food safety issues related to marketed vegetables in South and Southeast Asia (Kuo *et al.*, unpublished). Researchers accessed 160 articles for a detailed analysis. A total of 42 out of these 160 articles looked into pesticide residues in marketed vegetables. The vast majority (34 out of 42 articles) reported pesticide residues that were beyond Maximum Residue Limits (MRLs). Some of these pesticide residues detected in these studies were moderately hazardous and some even highly hazardous or extremely hazardous following World Health Organization standards.

Pesticide use is generally very high in LMICs in Asia because vegetables are highly susceptible to damage from insect pests and diseases, and pesticides are usually relatively cheap and easy to obtain. Schreinemachers *et al.* (2019) quantified the extent of pesticide overuse in vegetable production systems in Southeast Asia, using data from 1,000 farmers producing leaf mustard and yard-long bean in Cambodia, Laos and Vietnam. Results show that 100% of participating farmers in Vietnam, 70% in Cambodia and 59% in Laos overused pesticides. Overuse of pesticides endangers the health of producers and consumers, and is inefficient from an economic point of view because profits could be enlarged by applying fewer pesticides. Moreover, there is increasing evidence in Asia that consumers are willing to pay more for vegetables produced without pesticides. Surveys done with 185 consumers buying in four big supermarkets in Vietnam indicated a price premium of about 70% for organic vegetables (Hai *et al.*, 2013).

A total of 24 articles in the World Vegetable Center's survey were related to contamination by pathogenic microorganisms. In addition, microbial contamination may occur at the production level (e.g. through the use of grey water) and along the value chain (inadequate post-harvest handling and storage). Results are very hard to compare because of differences in methodology, but the general trend is that a significant share of samples tested positive for at least one pathogen. The most common foodborne pathogens on vegetables in Southeast and South Asia sold in both wet markets and supermarkets include *Salmonella* spp., thermo-tolerant *Campylobacter*, *Escherichia coli*, *Shigella* spp. and *Listeria monocytogenes* (Kuo *et al.*, unpublished). The incidence level and microbial load in fresh vegetables procured from supermarkets, grocery stores and local traditional markets is generally higher in comparison to vegetables collected from packing house operations and farm yard.

A total of 47 articles in this survey were related to contamination of vegetables by heavy metals. Contamination by heavy metals above WHO limits was related to particular local settings, for example, if a production site is near industrial activity or a busy road. Fruit vegetables (e.g. tomato, eggplant) are less likely to have harmful levels of heavy metals than leaf, stem or root vegetables.

### **Innovations enhancing availability and affordability**

Inclusion of micronutrient-dense crops in farmers' cropping calendar will insert much needed nutritional value into the supply chain. Traditional vegetables such as amaranth, okra, *kangkong* are more nutrient-dense than global vegetables such as tomato, cucumber and sweet pepper. They are also generally more robust and require fewer external inputs, reducing food safety concerns.

Farmers' crop yields are often much lower than what would potentially be possible with improved management practices. For open-field crops, more robust and better yielding varieties combined with alternative soil and water management options (e.g. drip irrigation) raises yield levels. Introduction of protected cultivation changes the growth environment and may enable year-round production, making vegetables more affordable and available.

Innovations to reduce the reliance on pesticides during the production stage include introduction of varieties that are more resistant to pests and diseases, grafting to overcome soil-borne diseases and enhance plant vigor, protective netting (sometimes impregnated with a pesticide), application of bio-pesticides, pheromone trap, other biocontrol agents such as predators, parasitoids, insect pathogens, etc., and integrated pest management practices.

Schreinemachers *et al.* (2016) evaluated an intervention in Bangladesh in which vegetable farmers were trained in off-season vegetable production methods, including the introduction of disease resistant, heat tolerant varieties and plastic roofs. This increased net household income by about 48%, but pesticide use also increased by 56%. Many farmers often spray as a preventive measure (de Bon *et al.*, 2014) because pesticides are relatively inexpensive while the risk of losing a crop due to pests and diseases is high. Lack of knowledge on what to spray, what not to spray, when to spray, when not to spray and how often to spray is a very common problem among smallholder farmers.

The challenge is to devise ‘baskets’ of technological innovations that are affordable to farmers and that are effective for different environments (soil and climate) and market conditions, to ideally permit year-round production. Introduction of forms of protected cultivation changes the growth environment and management practices will have to be reconsidered. In Asia, the entire spectrum is used from open-field to ‘plant factories’.

Combating post-harvest losses (which are estimated to be around 40% for vegetables in LMICs) is imperative and can be achieved through better storage, drying, and cooling technology and improved transportation and logistics. Simple drying or food processing helps to avoid post-harvest losses and transform vegetables into higher value products (e.g. nutritious snacks, dried vegetables). These processing technologies also help address seasonal limitations and make vegetable available for a longer time. More research is needed to evaluate the loss of nutritional content depending on how vegetables are stored, processed, and cooked.

### **Innovations that enhance acceptability**

Traceability and certification systems are important to build trust among consumers about the safety of vegetables. Such systems can be very sophisticated using bar-code, QR code, and spot checks with rapid bioassay of pesticide residues system developed by Taiwan Agricultural Research Institute. They can also be low-tech, based on building trust among consumers about the safety of vegetables and involve simple visits to the farm. Support can be provided to farmers to gradually achieve local certification standards to even global Good Agricultural Practices (GAP) standards for export.

### **Policy and regulatory interventions**

Policy and regulatory interventions may stimulate development of the horticultural sector, by providing subsidies on certain inputs, such as drip irrigation and protected cultivation structures.

It may also include the removal of ineffective or highly dangerous pesticides from the market, giving technical training on pesticide selection and use to farmers, and encourage the development of the bio-control industry. Many Asian LMICs are embracing biocontrol measures and speeding up legislation. Bangladesh for example has registered 24 bio-pesticides (microbial pesticides, neem extract, bio-inoculants, pheromone lures, etc.) and 64 bio-pesticides are in the registration pipeline.

## **3. GETTING IT TOGETHER: FOOD SYSTEMS CHANGE**

To achieve changes in food systems that enhance food safety and nutrition security at scale in a particular setting will require thorough analysis of dietary gaps and consumer behavior, the food environments where consumers of different purchasing power access their food, and the food supply chains, from production to marketing. Moreover, there is a need to consider the importance of external drivers on the food system as a whole (HLPE, 2017), i.e. biophysical and environmental drivers (e.g. natural resource base, climate change); political and economic drivers (e.g. conflicts and humanitarian crises); socio-cultural drivers (e.g. culture, women’s empowerment); and demographic drivers (e.g. youth unemployment, migration, urbanization).

The design of programs that aim to enhance vegetable production and consumption simultaneously requires the involvement of all relevant stakeholders (farming organizations, civil societies, public sector, private sector, knowledge institutions) and local policy and decision-makers from the beginning. Unfortunately, very little evidence is available on what works, when and where, and contributes to food safety and nutrition security. The literature focuses mainly on the effect of single interventions and innovations, addressing only part of the food system.

Given the complexity of food systems a classical, linear, activity-based approach is unlikely to lead to lasting positive outcomes. Instead, we advocate for a more ‘coaching or accompanying’ approach used by Pasiiecznik (2018), with ‘bridging institutions’ facilitating change, strengthening innovation capacities of all stakeholders, and using real-time monitoring and evaluation to learn and adjust approaches over time. Emphasis should not only be placed on technical capacities but also on functional capacities to stimulate collaboration, reflection and learning and engagement in strategic and policy processes.

## CONCLUSIONS

The paper provided an overview of vegetable innovations that have the potential to enhance food safety and nutrition security in Asian low and middle income countries. The authors used the HLPE framework (2017), distinguishing between innovations and policy interventions that target consumer behavior change (demand), the food environment (demand-supply) and food supply chains (supply). There is a lack of a research evidence base for what works well, where, and related cost-effectiveness.

Addressing supply-side opportunities and demand-side motives separately may not result in lasting positive outcomes. There is a clear need for piloting of food systems change in different settings, aiming to achieve a triple win: favorable dietary, economic and environmental outcomes at scale. This should be done through approaches that address the entire vegetable food system while considering external influences determined by climate change, the political and demographic context. Such pilot studies should respond to ongoing urbanization and the anticipated growing urban demand for quality vegetables. They should link the demand to short, local supply chains that produce safe and nutritious vegetables, accessible in both informal and formal market settings at affordable prices.

Although the world spends US\$ 620 billion in agricultural subsidies per year (OECD, 2018), there is still a large disconnect between public investments on staple food and the need for nutritious food. The same is true at the national level. In low- and lower-middle income countries, only one publicly-funded researcher per 1 million population on average is working on fruit or vegetables (Schreinemachers *et al.*, 2018). The vast majority of funding goes to staple grains including wheat, rice and maize, with very limited investment in fruit and vegetables (Shah, 2018; Voegele and Nelson, 2019). It is urgent to allocate a greater share of public and private research investments to fruits, vegetables nuts and legumes, which are what can be called ‘the new generation of staple foods’ for healthier diets.

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