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Measuring nutritional quality of agricultural production systems: Application to fish production

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ABSTRACT

Reorienting food systems towards improving nutrition outcomes is vital if the global goal of ending all forms of malnutrition is to be achieved. Crucial to transitioning to nutrition-sensitive agriculture is valuing and measuring nutritional quality of the outputs of agricultural production. We review existing indicators which capture an element of nutritional quality applicable to different stages of the food and nutrition system. Applying relevant indicators from the agricultural production stage to selected aquaculture systems, we compare and contrast their strengths and limitations. 'Nutritional yields', 'potential nutrient adequacy' and 'Rao's quadratic entropy' show particular promise in capturing the ability of a production system to nourish the most people and could be useful tools for prioritising investments and decision-making in the public, non-government and private sectors driving agriculture.

1. Introduction

Malnutrition in its various forms directly affects one third of the global population and combined with poor diets, is the leading driver of the global burden of disease (IFPRI, 2016). At the heart of this problem are food systems which are narrowly focused on maximising yields and economic value, without due consideration of the impacts on human health. Through the Sustainable Development Goals (SDGs), the world has committed to ending all forms of malnutrition (United Nations, 2015). Reorienting food systems across all actors and levels, towards improving nutrition outcomes (nutrition-sensitive food systems) is central to achieving this goal, as was recognised in the second International Conference on Nutrition (ICN2) Framework for Action (FAO and WHO, 2014). In line with this, The Global Panel on Agriculture and Food Systems for Nutrition has recently called for a paradigm shift in food systems thinking away from 'feeding people' to 'nourishing people', emphasising the importance of nutrition as an outcome of food systems (Global Panel on Agriculture and Food Systems for Nutrition, 2016). This is further strengthened in the recently declared United Nations (UN) Decade of Action on Nutrition 2016–2025 which aims to increase visibility of nutrition at the highest levels and ensure measurement of progress towards sustainable food systems (FAO and WHO, 2016). It is suggested here that a vital advancement in this pursuit lies in valuing and prioritising nutritional quality of agricultural production rather than yields alone. Decision-making at the farm level depends on a complex interplay of on-farm factors including socioeconomic and biophysical conditions; and off-farm factors including access to markets, support services (e.g. agricultural extension), scientific and indigenous knowledge, and policies, rules and regulations (French, 1995). The public sector, non-government organisations, and the private sector all play important roles in influencing such factors and therefore the production systems which farmers choose to adopt. It is envisioned that a clear and simple indicator of nutritional quality could assist decision-makers, through their traditional levers of influence (such as input subsidies, agricultural extension support, and market incentives), to encourage farmers to improve nutritional quality of production, and therefore progress this paradigm shift. The objective of this analysis is to examine indicators which capture the ability of a production system to nourish the most people which could be useful for decision-making in agricultural production systems.

Food systems can be conceptualised as consisting of all of the inputs and activities required to produce and distribute food for human consumption. Various conceptual models of food systems include several stages such as agricultural production (consisting of a number of subsystems), distribution, and consumption; each of which involves inputs, which undergo transformation and result in various outputs which

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continue their flow throughout the system (Global Panel on Agriculture and Food Systems for Nutrition, 2016; Ingram, 2011; National Health and Medical Research Council, 2013). Several authors propose a broader concept of food systems which incorporates nutrition and health outcomes, emphasising the interdependence of agricultural production, food consumption and nutritional status (Burchi et al., 2011; Nugent, 2011; Sobal et al., 1998). An advantage of this conceptual approach is that an understanding of the drivers of, inputs to, transformations within, interactions between, and outputs at each stage of the system allows more effective guidance of interventions at various stages in the system to achieve desired nutrition and health outcomes.

Within the food and nutrition systems framework (see Fig. 1), it is clear that nutritional quality of foods as consumed (the inputs of the consumption stage), in turn (albeit with varying and often considerable processing and transformation) rely on the nutritional quality of outputs from the agricultural production stage (whether at a local or global scale). It is recognised that processed foods play an increasingly larger role in dietary patterns across the world (Baker, 2016). However this should not detract from the fact that many whole foods, such as fruit, vegetables and animal- source foods, particularly in rural food systems still pass from production to consumption relatively unchanged in terms of nutritional value. The premise here is that whilst food processing and markets have a key role to play in improving food safety, reducing loss and waste, improving shelf life and providing convenient and nutritious foods; the basis of all foods (processed or not) must be *production* of high quality food. There is a large body of literature on methods and indicators for measuring nutritional quality of diets as consumed (see indicators related to the consumption stage in Fig. 1), however, significantly less work has been done on measuring nutritional quality of the outputs of the agricultural production stage. This is because agricultural production systems are not designed explicitly to meet the health and nutrition needs of populations; but rather, to maximise yield and economic gains for producers (Bouis and Welch, 2010). It is anticipated that calls to action for agriculture to become more nutrition-sensitive, will not be realised unless a nutritional quality dimension is incorporated into measurement of outputs.

There is on-going tension between the benefits of diverse agricultural production systems and the economies of scale feasible with less diverse systems, for achieving high quality diets (Fanzo, 2017). Greater on-farm production diversity can improve dietary quality of household members (Jones, 2014, 2017; Jones et al., 2014; Koppmair et al., 2017). On the other hand, a more market-oriented approach to production (assuming adequate access to markets) can increase income, allowing the household to purchase nutrient-rich foods (Koppmair et al., 2017; Sibhatu et al., 2015). However, as others have noted, this debate fails to capture the relationship between production and consumption across scales (Fanzo, 2017; Remans et al., 2015). Global food production has become increasingly homogenous (Khoury et al., 2014). In Bangladesh, increased supply of fish through rapid expansion of aquaculture has failed to improve nutritional quality of diets (Bogard et al., 2017). People are eating more fish, but intakes of vital micronutrients from fish have actually decreased, related to the generally lower nutritional quality of farmed species compared to the nutrient-rich small indigenous species from capture fisheries. This demonstrates that individual production sub-systems must have an impetus to maximise nutritional quality, irrespective of market orientation.

This study presents a comparative analysis of the merits and limitations of existing indicators that capture some elements of nutritional quality of the outputs of agricultural production sub-systems (individual systems within the production stage of the broader food and nutrition system, Fig. 1). First, a brief summary of available indicators, how they are calculated and a discussion of some of the contexts in which they have been previously applied, is provided. Next, a case study of aquaculture production systems in Bangladesh (as an example of an agricultural production sub-system) is presented as the context for application and comparison of selected indicators. The conclusions drawn from this analysis are used to inform recommendations for inclusion of appropriate indicators in the evaluation of agricultural production sub-systems to maximise their potential to not only feed people, but to nourish them.

2. Methods

Two comprehensive collections of indicators have been published recently which are highly relevant for this analysis. The first is a user's guide for 33 types of existing indicators that measure the various dimensions of food and nutrition security published by the Food Security Information Network global initiative and essentially provides a benchmark for the adequacy of the food and nutrition system (Lele et al., 2016). The second is a compendium of 58 indicators for nutrition-sensitive agriculture published by the Food and Agriculture Organization, which presents a best-practice guide for measuring the impact of agricultural interventions on nutrition (Herforth et al., 2016). An additional indicator (nutritional yield) not captured in the above reviews, but highly relevant to this analysis, was identified in the recent literature and so is included here (DeFries et al., 2015). Indicators from these sources were examined for their relevance in capturing some aspects of food/nutrient availability, access, consumption or utilisation ($n = 43$). Indicators which capture important determinants of nutrition and health outcomes, but are not explicitly relevant to food or nutrients were excluded from this analysis (e.g. indicators of sanitation, income, women's empowerment). Applicable indictors were then categorised according to the relevant food and nutrition system stage (see Fig. 1), based on the scale at which data is collected in order to calculate the indicator (e.g. the indicator 'availability of specific foods in markets' is based on data collected at the market level, and so grouped in the distribution stage). Indicators relevant to the agricultural production stage were then further examined; indicators ($n = 4$) which are only relevant in the context of total food supply and therefore are not useful for decision-making around individual production sub-systems (e.g. sub-systems 1.1–1.5, in Fig. 1), are listed in Fig. 1 for completeness, but are excluded from further analysis. For example, a common indicator used by the Food and Agriculture Organization (FAO) as a reflection of nutritional quality of the food supply, is the percentage of dietary energy from non-staple foods, with a high proportion of energy from non-staple foods reflecting a more diverse food supply. However, this indicator does not offer any interpretation of the nutritional quality of outputs from an individual production sub-system, such as a rice production system.

Based on this process, two groups of indicators were identified that are relevant for further discussion as measures of nutritional quality of the outputs of agricultural production sub-systems; nutritional yield, and measures of functional diversity (including production diversity). It is noted that the various indicators discussed here are only relevant to agricultural production that is destined for human consumption and therefore excludes crops such as tobacco, cotton and jute. A summary of each relevant indicator, including a description, method of calculation, strengths and limitations is included in Table 1.

3. Indicators of nutritional quality of agricultural production

3.1. Nutritional yield

Nutritional yield is defined as the "number of adults who would be able to obtain 100% of the dietary reference intakes (DRI) of different nutrients for one year from a food item produced annually on one hectare" (DeFries et al., 2015). It is calculated separately for individual nutrients, which could be combined into an index score of selected nutrients of interest in a given context. So far, this indicator has been applied to cereal crop production in two studies, one in India (Defries et al., 2016), and one on the global scale (DeFries et al., 2015). A modified version of this indicator was also included in recent analyses