Nutrition Research Agenda in the Context of Nutrition Problems in Tanzania - a Critical Review

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Abstract

Historically, preventing undernutrition (stunting, wasting and underweight) has proven to be very difficult. Broad, food-based counsel is generally too superficial, and multiple nutrient deficiencies often occur even when food recommendations are followed. Advances in dietary assessment and planning over the past 10 years have enabled more precise estimates of nutrient intake and nutrient need. The recommended nutrient intake (RNI) in areas with high rates of stunting and underweight are now available. However, bioavailability is a major constraint for some nutrients, particularly in plant-based diets when food fortification or the use of nutrient supplements does not occur. Inadequate control of infectious diseases is a major factor limiting nutrient utilization and causing poor development of the immune system in young children. The role of mycotoxins in poor immune system development and poor growth is becoming increasingly apparent, but additional research is needed in this area. A number of key research agendas have been identified, which include the need to identify what nutrients are necessary, other than vitamin A, iodine and iron, which are being consumed in inadequate quantities in Tanzania; to establish a country-specific food composition database; to develop appropriate technologies, which can be easily adopted, for preserving and processing foods; to investigate the effects of exposure to mycotoxins on nutritional status and growth; to identify appropriate complementary foods for Tanzanian children; and to investigate the economics of improving nutritional status by promoting animal-based food products in Tanzania. Others research areas include an investigation into the unique cultural dimensions of dietary intake in Tanzanian society; the nutrient requirements for people who have various common illnesses, such as malaria; and the effects on the nutrient content of foods grown under climate change stresses, e.g., moisture and temperature.

Keywords: Nutrition research gap; innovative nutrition research agenda; nutrient bioavailability; Nutrient deficiencies.

Introduction and scope of the review

The WHO states that "food security" is built upon three pillars—food availability, food access, and food use (WHO, 2013). The Human Nutrition theme is related to pillars two and three, i.e., having adequate knowledge and resources to obtain and use foods to maintain a healthy and active life. Having food available and the resources to obtain foods to allow for dietary preferences is necessarily the first step toward food security. However, a basic understanding of nutrition is required to guide food choices so that appropriate amounts of nutrients and energy are consumed. The nutrients in the food supply must then be absorbed before they can be utilized by the body - a fact often ignored during dietary assessment and planning. Since health metrics are used to assess overall food security, other factors that influence health must be considered. Food safety—acceptable levels of microbes and mycotoxins, a source of safe water for consumption and food preparation, and good hygiene—is critical. Only when the appropriate amounts of nutrients and energy are absorbed and there is an absence of factors that hinder nutrient utilization can nutrients in food be utilized for growth, maintenance, and a healthy, active life. It is common to see children in Tanzania who are underweight and/or stunted, and it is likely that inadequate nutrient ingestion and absorption are the major causes of inadequate weight gain and linear growth. To address these concerns, a number of research areas are explored in this section. These include quantifying the amount of food consumed, dietary adequacy, effective interventions to reduce undernutrition, bioavailability of nutrients, and exposure to mycotoxins and their link to the impairment of immune development.

Review

Quantifying the type and amount of food consumed

A necessary first step in identifying the cause(s) of inadequate growth is to accurately quantify the type and amount of food consumed. This is usually done through either dietary assessment or dietary planning although use of a diet quality index (Angelopoulos et al., 2009) is gaining popularity. Dietary assessment is frequently done by first obtaining an estimate of what is consumed per unit of time. Food recalls, food diaries, and food frequencies are commonly used to assess food intake (Vucic et al., 2009). In reality, it is very difficult to obtain accurate food intake data regardless of the method utilized. Even food intake data gathered by "validated" methods should be considered approximations rather than precise representations of amounts consumed. Since foods are generally consumed as a mixture of ingredients, a typical recipe needs to be determined so that the amount of each ingredient in the composite food can be calculated. There are a number of food composition databases available to calculate the amount of nutrients present in a given amount of food or ingredient. Country-specific food composition databases are preferable, but if such a database does not exist, or if the accuracy of the database is questionable, then large international food composition databases are acceptable. A first Tanzanian Food Composition Table (Lukmanji et al., 2008) has recently been compiled, but it is still far from being complete or sufficient.

Commercially available spreadsheets and macros can be a great aid in calculating nutrient intake. Comparing nutrient intake to how much of a nutrient needs to be consumed is perhaps the most straightforward part of dietary assessment, and nutrient needs or requirements are well established. The FAO/WHO have updated their estimates of nutrient requirements (FAO, 2001; 2004; WHO, 2007), as have the Institute of Medicine for the US and Canada (Otten et al., 2006). The required nutrient intake established by the two agencies are in general agreement, but the FAO/WHO recommended nutrient intakes (RNI) are considered the most appropriate for Tanzania where there are discrepancies between the two agencies.

There are many software programs available that can calculate nutrient intake and nutrient adequacy. A major limitation for using these programs is that the food composition databases included in the software often do not incorporate the foods typically consumed in developing countries. In addition, the software user needs to realize that the nutrient intakes may need to be compared to the RNIs suggested by Golden (2009) rather than to the RNIs built into the software. NutriSurvey is a suitable program for use in Tanzania and can be downloaded at no charge (NutriSurvey, 2010). Several food composition databases and instructions for using the program can also be downloaded from the same site. Furthermore, if the appropriate food is not in a database, foods can be added to the databases provided the nutrient content of the food is known.

The RNIs published by FAO/WHO and the Institute of Medicine assume that the diet is planned for healthy individuals with no nutrient deficiencies who live in a "friendly" environment. Obviously this does not describe the majority of Tanzanians. For individuals with nutrient deficiencies (underweight and/or stunted) and living in a "hostile" environment, a different set of RNIs are necessary. Golden (2009) published an excellent article detailing nutrient requirements for children from six months to five years of age. He explained why RNIs should be stated in terms of nutrient density (amount of nutrient per 1000 kcal) rather than age or weight, particularly when underweight or stunting is present. For underweight and stunted children, additional energy and nutrients must be provided for "catch-up growth." He provides RNIs for moderately malnourished children that are designed to allow catch-up growth. When dietary assessment programs are used in situations where underweight and stunting are prevalent, the RNIs for moderately undernourished children are used.

Dietary adequacy (or inadequacy)

Dietary assessment considers whether or not adequate kinds and amounts of food are being consumed to meet nutrient requirements, while dietary planning deliberates whether or not the available foods provide the RNIs if the foods are consumed in reasonable quantities. For dietary planning, one must know what foods are available and the portions of these foods that a person can reasonably eat in a day. Similar to dietary assessment, dietary planning requires one to know the nutrient content of foods that are available for consumption, the quantity of each food consumed, and the amount of each nutrient required. Linear programming is a mathematical approach that efficiently answers whether or not the available foods can provide all of the required nutrients. If local foods can provide all of the nutrients, linear programming can determine the lowest-cost diet that provides all of the required nutrients. Briend et al. (2003) and Darmon et al. (2002) describe how to perform linear programming using Microsoft Excel. NutriSurvey has a linear programming module, which can be downloaded for free, designed to develop nutritionally adequate complementary foods for 6–23 month old infants (NutriSurvey, 2010). Several nutrient databases and instructions for using the linear programming module are available for free download on the same site. It should be kept in mind that the lowest cost diet may not be palatable or culturally acceptable (Maillot, 2010), and alternative diets must then be devised. The trial-and-error technique of dietary planning can provide the same answers as linear programming but at the cost of much tribulation—especially for those who are not experienced in diet planning. Even experienced diet planners find it difficult to design a low-cost diet that has adequate amounts of all nutrients. A free publication provides numerous suggestions and practical applications to assist when using RNI for dietary planning (Food and Nutrition Board, 2003).

Plant-based diets that lack variety are often deficient in several nutrients. Diet planning, as described above, and some dietary assessment software programs will estimate nutrient deficits. There are several options available to fill nutrient gaps. One option is to determine what foods can be grown or purchased to provide the deficient nutrients. While there are many examples of successful small-scale interventions using this approach documented (Leroy et al., 2010; and Aphane et al.; Arimond et al.; Chadha et al.; Englberger et al.; Faber and Laurie; Muehlhoff et al., 2011), long-term, large-scale interventions are lacking. Food fortification and/or nutrient supplementation will most likely be required to provide a nutritionally adequate diet if the diet is plant-based and limited in variety. There are numerous examples of successful strategies utilizing multiple micronutrient supplements to improve maternal nutrition outcomes and infant growth (Bhutta et al., 2008; Imdad et al., 2011; Kraemer et al., 2012). Most, if not all, developed countries utilize food fortification and supplementation to increase the intake of deficient nutrients. The current thinking of international agencies, including Feed the Future (FtF), seems to be that a diverse diet approach can solve much of the nutrition problems in an ideal world. However, this is not an ideal world and utilizing a diverse diet as the only approach will not result in the growth and healthy life that is envisioned by proponents of FtF. Not utilizing food fortification and supplements and expecting good growth and a healthy life is analogous to not using fertilizer and expecting good yields when plants are grown in poor soils. Not providing the necessary nutrients will limit growth and production, whether you are dealing with plants, animals, or humans.

Nutrition recommendations are often food-based, i.e., require the consumption of certain amount of foods in each of several food categories. While this approach is simple, it is largely unsuccessful unless there is concomitant consumer education. Even with education, the recommendations need to be finite and include only available foods or foods that could be available from local markets or grown by the family (Ashworth and Ferguson, 2009) if this approach is to be successful. Getting people to eat the appropriate amount of foods to obtain all of the required nutrients and energy has proven to be very difficult even when food security exists (IFPRI, 2014).

Many vitamins need to be consumed on a daily basis because there is minimal storage of these nutrients in the body. Fruits and vegetables tend to have short harvest seasons, and spoilage results within a few days of harvest unless there is a suitable method of preservation to allow prolonged storage of these highly perishable foods. Lack of food preservation is a problem particularly in rural areas, but it also presents a constraint for urban consumers. Tanzania produces a wide variety of fruits, but the lack of inexpensive processing to allow storage and widespread distribution and consumption is a major problem. Adequate food preservation knowledge exists, but the adaption of the technologies to make them suitable for use in Tanzania is lacking. At a household or an individual level, the need for food preservation is a necessary component of nutrition education. The use of solar energy for drying and thermal processing is just one example of an underutilized technology that could preserve food and minimize food losses. There will inevitably be unavoidable losses of the most labile nutrients, such as vitamin C, folate, thiamin, and riboflavin, during drying or thermal processing, but the remaining amounts may be adequate, and the intake of other vitamins would be significantly improved by the consumption of preserved fruits and vegetables.

Effective interventions for reducing undernutrition

Recent reviews (Bhutta *et al.*; Morris *et al.*; 2008; and Lutter *et al.,* 2011) conclude that effective interventions for reducing undernutrition are known, however, it is the limited implementation and coverage of these interventions that are mainly responsible for the meager gains in preventing and correcting undernutrition. Morris *et al.* (2008) maintain that little progress is being made because of ineffective use of resources. Lutter *et al.* (2011) concluded in their review that poor feeding practices and the failure to implement key interventions were largely responsible for the 19.3% underweight, 38.2% stunted, and 10% wasted of 6–23 month old infants in Africa (Countdown Core Group, 2010), while Bhutta *et al.* (2008) reviewed publications describing interventions aimed at preventing maternal and child undernutrition and resulting nutritional outcomes. Strategies to promote breastfeeding significantly improved infant survival, but they did not reduce stunting. In populations where food was not secure, providing food supplements with or without education reduced stunting whereas providing education about appropriate complementary feeding in food secure populations also reduced stunting. Using modeling techniques, they predicted that stunting at 36 months of age could be reduced by 36 percent through the implementation of the strategies they reviewed (Bhutta *et al.,* 2008). They felt that poverty, lack of education, infectious diseases, and a lack of women's empowerment all contribute significantly to stunting and must be addressed. Furthermore, strategies aimed at improving nutritional outcomes need to be implemented if stunting is to be prevented in the future.

Clinical trials have been conducted in Tanzania since 2000 (Fawzi *et al.,* 2000; 2003; 2004; 2005; 2007; Kupka *et al.,* 2008; Villamor *et al.,* 2000; 2002; 2006) to establish the influence of nutrients supplementation on diseases, child growth and pregnancy outcomes. The clinical trials have shown that long-term multivitamin supplementation to HIV pregnant mothers delays the progression of HIV, improves poor growth in children, improves the pattern of weight gain in pregnant women, and improves the vitamin status of both pregnant women and infants. While such findings can be very useful in the management of severe acute malnutrition and other therapeutic interventions, they have not been fully integrated into the Tanzanian health care system.

Concern for poor bioavailability of nutrients

Bioavailability can be described as the portion of a nutrient in food that is absorbed and utilized by the body. A number of variables, such as phytate and polyphenolic content, method of food preparation, and types of foods in a meal can increase or decrease the bioavailability of a nutrient (FAO, 2001; 2004; Otten et al., 2006; WHO, 2007; Maiani *et al.,* 2009; Fairweather-Tait and Collings, 2010; NutriSurvey, 2010). For example, the amount of iron in a plant-based diet needs to be 4–5 times the amount of iron in a diet containing a significant amount of meat because of the low bioavailability of iron in plant foods (FAO, 2001). Also, consuming a citrus product with plant foods containing iron can significantly increase the bioavailability of iron in that meal. The low bioavailability of critical nutrients, such as iron, zinc, the provitamin form of vitamin A (carotene), and folic acid, is particularly important for populations consuming primarily plant-based foods. When the FAO/WHO publication (FAO, 2001) is used to calculate RNIs for iron or zinc, one must select whether the overall diet has a low, medium, or high bioavailability of these nutrients. For most Tanzanian diets, the RNIs associated with low bioavailability should be utilized.

The importance of bioavailability is shown in a recent study that measured the efficacy of the iron biofortification of dry beans (Petry *et al.,* 2012). Using traditional breeding and selection methods, the iron content of a bean was increased by 77 percent. Based on the simple iron content of the biofortified beans, adding the biofortified bean to a diet should have significantly reduced anemia in a group of mildly anemic women. However, because iron in plant foods is only about five percent bioavailable, the significant increase in iron content of the bean had a limited impact on the consumer (Petry *et al.,* 2012). Another example of how bioavailability can be extremely important is related to the nutrient requirement for promoting catch-up growth in stunted children. The phosphorus content of plant-based diets is generally adequate for normal growth. However, children that are moderately stunted (<2.0 HAZ score) require additional phosphorus for bone growth (Golden, 2009). Much of the phosphorus in plant foods is present as inositol-phosphate (phytate) and is not bioavailable. Thus all phosphorus present as inositol-phosphate should be subtracted from the total phosphorus content of the diet, and only the phosphorus in the diet that is not present as inositol-phosphate should be considered as available for absorption and use by the subject. There are a number of commercial and home food processing techniques, such as milling, dehulling, fermentation, or germination, that can be utilized to improve nutrient bioavailability (Abebe *et al.*; Chana *et al.*; Gibson; Hotz and Gibson, 2007; Golden, 2009; Michaelsen *et al.,* 2009). A critical consideration is that most of the techniques require a significant amount of work to enhance bioavailability, and the challenge will be whether or not consumers can be convinced that the improved nutrient bioavailability is worth the additional time and effort. Furthermore, some of the food preparation techniques that improve the bioavailability of iron, zinc, and phosphorus may reduce the content of thiamin, riboflavin, vitamin C, and folic acid (Hotz and Gibson, 2007). So the impact of these food preparation techniques on overall nutrient intake must be considered.

While consideration for bioavailability is an important aspect of nutritional improvements in Tanzania, only limited and scattered studies have been reported in the country (Mosha et al., 2000; Towo et al., 2006; Tatala *et al.,* 2007; Ngegba *et al.,* 2009; Mduma *et al.,* 2012). A team of researchers from the Sokoine University of Agriculture (SUA), in collaboration with the World Vegetable Centre (AVRDC), have used in vitro techniques to investigate the bioavailability of iron in the dishes of cooked African indigenous leafy vegetables commonly consumed in Tanzania (Ngegba *et al.,* 2009; Mduma *et al.,* 2012).

Exposure to mycotoxins and impairment of the immune system

Infants are born with a very immature immune system, and therefore infants and young children must be adequately nourished in order for their immune systems to develop fully. A deficiency of any of the following nutrients can impair immune development: vitamins—A, C, E, B6, B12, and folate; minerals—zinc, selenium and iron; protein; and fatty acids—linoleic and linolenic acids (Katona and Katona-Apte, 2008; Darnton-Hill and Ahmed, 2009; Florentino, 2009; Jones *et al.,* 2010; Wild and Gong, 2010; Dewey and Mayers, 2011; Grant *et al.,* 2011). Because of their immature immune system, infants suffer from repeated incidences of diarrhea and infections. If nutrient deficiencies exist and normal immune development is impaired, the infant will suffer from a greater degree of diarrhea and infections. The infectious diseases themselves increase nutrient requirements, and a vicious cycle of nutrient deficiency is created, leading to more infections, which leads to greater nutrient deficiencies, and so on. Young children in East Africa are exposed to parasites and malaria (Premji *et al.,* 1995; Friis *et al.*; Stoltzfus *et al.,* 1997; Olney *et al.,* 2009), which further exacerbates nutrient deficiency, resulting in an increased infection cycle. Exposure to mycotoxins adds an additional layer of complexity. The mycotoxins aflatoxin and fumonisin suppress immune function and cause growth retardation in farm animals, poultry, and laboratory animals (Bondy and Pestka, 2000; Jiang *et al.,* 2008; Wild and Gong, 2010). Therefore it is highly likely that, if humans are exposed to mycotoxins, growth retardation will occur. Kimanya *et al.* (2010) reported that fumonisin levels in complementary foods in Tanzania were sufficient to cause growth retardation.

3. Conclusion: Proposed innovative nutrition research agenda for Tanzania

Based on the above review, six areas of research agenda are proposed. The areas include:

- Need to assess nutritional status of other nutrients apart from the traditional vitamin A, iodine, and iron in the population. These may include essential fatty acids (e.g. linoleic and linolenic acids); some minerals such as selenium, zinc and manganese; vitamins (e.g. riboflavin, thiamin, niacin, folic acid and cobalamin); and essential amino acids.
- Developing a country-specific food composition database
- Investigation to identify adoptable and appropriate technologies for preserving and processing locally produced foods
- Investigate the effect of exposure to mycotoxins and impairment of the immune system
- Investigation to identify of Appropriate foods for Tanzanian children
- Economics of improving nutrition status by promoting animal-based food products

i) Nutrient status

Other than vitamin A, iodine, and iron intakes, it is not clear what other nutrients are being consumed in inadequate quantities. An example of an approach to provide the needed knowledge would be to use biomarkers of nutrient status to identify which nutrients are not being absorbed in adequate amounts. Examples of biomarkers are the following: urinary excretion of methyl malonic acid to detect insufficient intake of vitamin B12; hemoglobin, soluble transferrin receptor, and C-reactive protein levels to distinguish iron deficiency from other problems associated with iron metabolism or other nutrient deficiencies; serum transferrin levels to assess iron stores; and serum retinol-binding protein as an indicator of vitamin A status. Other biomarkers include excretion of thiamin and thiamin metabolites in urine to assess thiamin intake; excretion of riboflavin and riboflavin metabolites in urine to assess riboflavin intake; the ratio of C20:3n-9 to C20;4n-6 fatty acids in blood cell membranes to assess intake of the essential fatty acid linoleic acid (use dried blood spots); and the ratio of C20:4n-6 to C20:5n-3 fatty acids in blood cell membranes to assess intake of the essential fatty acid linolenic acid (use dried blood spots).

ii) Lack of country-specific food composition database

It appears that, while country-specific food composition databases are preferable in calculating the amount of nutrients present in a given amount of food or ingredient, no comprehensive databases are available for Tanzania. Researchers in the country have continued to use large international food composition databases, such as the FAO/WHO. In this situation, the resulting estimates are unlikely to be accurate. There is therefore need for researchers to work and compile a national food composition database.

iii) Adoptable and appropriate technologies for preserving and processing foods

One of the factors causing failure to attain dietary adequacy among Tanzanians is a lack of inexpensive processing technologies to allow storage and widespread distribution and consumption of the wide variety of fruits and vegetables that are available in the country. Although food preservation knowledge exists, adoption of the technologies to make them suitable for use in Tanzania, especially in rural areas, is lacking. Therefore there is a need for researchers to investigate and design appropriate technologies that can be adopted in the rural context where the availability of electricity can be quite limiting. Specific potential research questions include:

- Are soaking, fermentation, and germination viable approaches to increasing nutrient bioavailability considering the labor requirements versus the improved bioavailablity of micronutrients—particularly for zinc, selenium and iron?
- What are the limitations for adopting the new ideas that are made available by various agents?

iv) Exposure to mycotoxins and impairment of the immune system

There are three questions that need to be addressed:

- Is inadequate immune system development primarily due to inadequate intake of required nutrients, frequent illnesses or are foods fed to children contaminated with mycotoxins?
- Given the existing knowledge of nutrition damage that can occur due to exposure to mycotoxins in foods, what is the extent of the contamination of foods used for infants and young children feeding (both commercial and homemade) in Tanzania?
- What food handling practices are effective in minimizing mycotoxin production in food staples?

v) Appropriate foods for Tanzanian children

A number of issues need to be addressed here:

- What are appropriate, locally available complementary foods for Tanzanian children aged 6–60 months? (The use of linear programming is suggested to determine what nutrients need to be supplemented and at what levels.)
- Is there a need for commercial production of complementary foods? And if there is such a need, what foods would be appropriate? (Again, linear programming could be useful to determine the appropriate nutrient supplementation.)
- What nutrition education methods and approaches are effective for adopting best practices in terms of complementary feeding?

vi) Economics of improving nutritional status by promoting animal-based food products

It is a true fact that nutrients in animal products are much more bioavailable than nutrients from plants. However, there are issues in Tanzania that need to be investigated:

- What is the relative cost of increasing nutrients intake via animal products versus food fortification and food supplements?
- What proportion of dietary energy should be derived from animal products to achieve a significant improvement in nutritional status?
- What are the societal costs for animal systems in order to improve nutritional status?

Other research agendas for consideration

- An investigation into the cultural dimensions of dietary intake in the country, with special attention to unique ones, to determine both the positive and negative aspects.
- The dietary requirements for people who are exposed to various stresses common in Tanzanian society, e.g., malaria.
- The effects on nutrient content of foods (vegetables, fruits, cereals, tubers) grown under climate change stresses, e.g., moisture and temperature.

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