

9 Biodiversity's contribution to dietary diversity

Magnitude, meaning and measurement

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Introduction

Biodiversity refers to the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species (genetic diversity), between species and of ecosystems.

(United Nations Environment Programme, 2002)

Recent publications (Frison et al., 2011; Bélanger and Johns, 2008; Burlingame et al., 2009a), and chapters within this book are increasing the focus upon biodiversity and its role in improving nutrition. At times a relationship between higher biodiversity and improved nutrition is assumed, without explanation of the type of biodiversity in question, documentation of supporting research, or a theoretical framework for expecting such a relationship. In this chapter, the basis for a potential relationship between biodiversity and nutrition is described, and the basis for biodiversity's nutrition benefits is elaborated.

Three links between biodiversity and nutrition

Biodiversity may be linked to nutrition in three different ways: at a macro level, at a farm level, and at a dietary level. At a macro level, biodiversity plays a role in “environmental services” that have a positive influence in agriculture and food production, including adaptation to climate change, soil protection, crop pollination, and pest control (Snapp et al., 2010; Frison et al., 2011). All the services contribute to longer term farm well-being, food supply stability, food security, and ultimately nutrition.

At the farm level, biodiversity (as crop diversity) can lead to greater production (Myers, 1996), sustainability (Brussaard et al., 2007; Frison et al., 2011) and stability (Zhu et al., 2000). Factors increasing production include niche differentiation (different crops taking advantage of favourable temporal and spatial on-farm niches); reduced loss to pests and diseases and weed competition and more efficient use of natural resources (e.g., different crops

access different soil nutrients, and in the case of legumes, increased nitrogen available in the soil for other crops to use) (Frison et al., 2011). Stability in production results from greater disease suppression in mixed crops (Zhu et al., 2000). Biodiversity in production systems minimizes vulnerability to existing and emerging stresses that is experienced in monocultures (Frison et al., 2011), allowing for longer term sustainability in production.

The focus of this chapter is on the role of biodiversity at the dietary level. Biodiversity has been proposed to be a prerequisite or correlate for dietary diversity and the health benefits that follow from having a diverse diet (Penafiel et al., 2011; Bélanger and Johns, 2008), and, depending on how biodiversity is defined, such a relationship is automatic – many different plants or animals must be cultivated or gathered to produce diversity on the plate – but whether multiple varieties of single plant or animal species are required for a diverse diet is not usually discussed in the biodiversity literature.

The following section reviews what dietary diversity means, how it is measured, and summarizes dietary diversity at a global scale. We then review the arguments made and the evidence for a relationship between biodiversity and dietary diversity. The next section considers the magnitude of biodiversity from a nutrition perspective, and presents the case for how biodiversity and dietary diversity could be considered in nutrition programming in a rural Bolivian population. The conclusion integrates the information from across the sections to generate a series of questions that should be considered prior to embarking on a biodiversity-based nutrition intervention.

Dietary diversity

Meanings and measurement

Dietary diversity is defined as the variety of foods in a diet over a given period of time (Ruel, 2003). National dietary guidelines consistently recognize and promote the importance of diverse diets (Health Canada, 2007; US Department of Agriculture and US Department of Health and Human Services, 2010; World Health Organization, 1996; German Nutrition Society, 2005). The basic diversity concept is simple, relatively easy to explain, and therefore intrinsically desirable for programme managers developing nutrition education messages. However, there is no consensus among the nutrition community as to what precisely constitutes a diverse diet or how to measure it.

Dietary diversity is typically measured by counting the number of different foods or food groups in a diet. A variety of scores have been developed for this purpose. Research in low-income settings has tended to emphasize simple food variety and diet diversity scores measuring the number of different foods and food groups, respectively, in the diet (Onyango et al., 1998; Arimond and Ruel, 2004; Rao et al., 2001) while research in wealthier countries has similarly relied on these types of count measures, but has also employed scales with scores based on meeting goals for recommended intakes of specific nutrients (e.g.,

energy, saturated fat, dietary cholesterol, calcium, sufficient servings of fruits and vegetables) (Drescher et al., 2007; Kant, 2004; Kennedy et al., 1995). A multivariate approach has been used in a newly developed method for calculating “nutritional functional diversity” (Remans et al., 2011). The differences in the emphasis and levels of simplicity of the measurement tools employed speaks to the diverse nutrition challenges (i.e., undernutrition, overnutrition, and the overlapping of the two) facing different population groups and the variation in the nutritional significance of diversity across contexts.

Sensitivity and specificity analyses can be conducted to determine the relevant cut-off points for the number of individual foods or food groups necessary for an individual to achieve an adequate dietary intake (Food and Nutrition Technical Assistance Project, 2006). However, these cut-offs points are difficult to generalize outside the specific contexts within which data are collected.¹ Fundamental decisions regarding even the selection of foods and food groups to include in diversity measures are highly dependent on the local availability of different foods, the nutritional content of these foods and the frequency of their consumption by different population groups (Ruel, 2003). Furthermore, emphasizing only foods or food groups in diversity indicators may fail to account for important nutritional variation within species (i.e., subspecies, varieties, cultivars, breeds) (Burlingame et al., 2009b).

Despite the multiple approaches used to measure dietary diversity and the varied determinants of diversity across locales, findings from multiple contexts consistently confirm the importance of including a diverse selection of foods in diets. Adult and child diets containing a greater number of different foods or food groups are associated with greater energy and nutrient intakes (Kant, 2004; Rose et al., 2002; Ogle et al., 2001; Tarini et al., 1999; Onyango et al., 1998) as well as more adequate nutrient intakes (Torheim et al., 2004; Steyn et al., 2006; Hatløy et al., 1998).² Furthermore, it is positively associated with adult and child nutritional status (Savy et al., 2005; Rah et al., 2010; Arimond and Ruel, 2004), birth weight (Rao et al., 2001), and further “downstream” health outcomes, including better cognitive function (Wengreen et al., 2009; Clausen et al., 2005), improved haemoglobin concentrations (Bhargava et al., 2001; Siegel et al., 2006), a reduced incidence of cancer (Jansen et al., 2004) and decreased mortality (Kant et al., 1993).

These improved health outcomes likely result in part from the greater likelihood that an individual will attain his or her energy and nutrient requirements from a more diverse diet, but the reason that these are achieved may not be obvious. First, there is some evidence of a “buffet effect” (i.e., when there is more food variety available, people will eat more) (Herforth, 2010). Secondly, there are nutrient density differences (mg of vitamins and minerals per gram of food, or per joule of food) at different levels of dietary diversity. Individuals with very low diversity diets (usually the very poor, very food insecure) have diets dominated by staple foods, which in most settings are starchy cereals, roots or tubers and are of relatively low nutrient density. At slightly higher levels of diversity in the slightly less poor, a few fruits and vegetables are added, and these

bring nutrients not present or in low concentration in the staple food. At still higher levels of diversity, there are more fruits and vegetables bringing in more nutrients, and at the higher levels still, nutrient-dense animal-source foods (e.g., meat, eggs, milk) are eaten, increasing the likelihood that the consumer will meet her nutrient requirements. So while adding rice to a corn-based diet will make it more diverse, it would not greatly increase nutrient intake as is usually intended and expected as dietary diversity increases. In fact, higher dietary diversity is more strongly associated with increased consumption of non-staple foods (e.g., animal-source foods, fruits and vegetables) compared with increased variety within a staple food group (Hoddinott and Yohannes, 2002). However, diverse diets convey benefits beyond just enhanced nutrient intakes.

Foods are not merely nutrient delivery devices, but complex mixtures of chemical compounds and elements anchored in cultural contexts whose many constituents act as agonists and antagonists to digestion and absorption in the gut and may have beneficial health effects independent of their nutrient content (Liu, 2003). Notwithstanding advances in nutritional biochemistry, a comprehensive understanding of human biochemistry, particularly with regards to the dynamics of “food synergy”, or the interactions between the various components of the food matrix, is a distant goal (Jacobs and Tapsell, 2007). Research on the relationships between single foods and nutrients is important in advancing nutritional science, but there may be greater public health significance of elucidating relationships between dietary patterns and health outcomes (Mozaffarian and Ludwig, 2010). These patterns, in fact, exhibit more consistent relationships to health outcomes than foods and nutrients alone (Slatterly, 2008).

Global landscape of dietary diversity

Food variety and food group diversity scores vary widely between countries (Ruel, 2003). Across all world regions, grains, roots and tubers contribute the largest percentage of energy to diets with all other food groups contributing less than 10 per cent (with the exception of meat and fish) (Figure 9.1) although on a weight basis (i.e., grams per person per day) consumption of fruits and vegetables is similar to grains, roots and tubers in the Americas, Mediterranean and Europe (Figure 9.2). But the regions are not homogenous, and Figure 9.3 demonstrates intra-regional differences in dietary diversity. Consumption of animal-source foods in most countries of the Americas is greater than that of African countries; however, large disparities exist even within the Americas, with the per capita consumption of animal-source foods in the United States quadruple that of Bolivia and more than 12 times that of Haiti.³ Several studies have found significant positive associations between dietary diversity and household socioeconomic status within countries (Thorne-Lyman et al., 2010; Rashid et al., 2006; Rah et al., 2010; Hoddinott and Yohannes, 2002; Hatløy et al., 2000; Anzid et al., 2009). Differences in socioeconomic status likely account for some of the variance between countries as well.

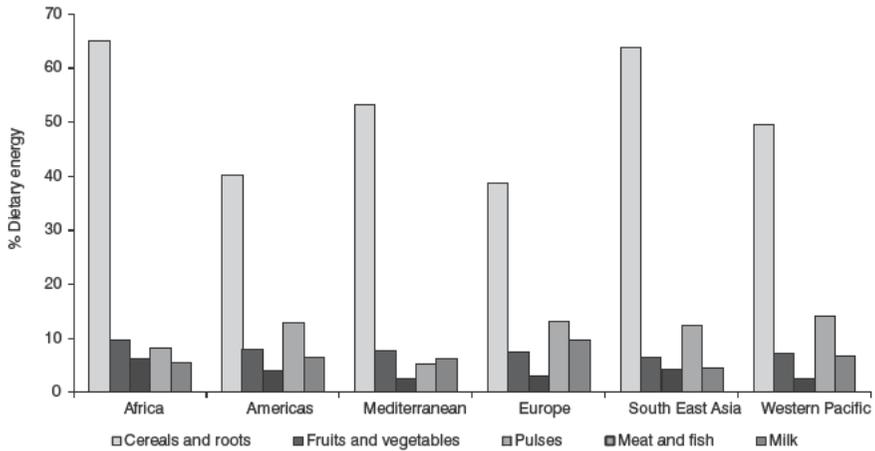


Figure 9.1 Consumption of select food groups as a percentage of total dietary energy by world region

Note: Data from FAOSTAT 2005–2007. The consumption amounts are the quantity of food estimated to be available for human consumption, but actual consumption may be lower due to wastage and losses during storage, preparation, thrown out or given to animals (<http://faostat.fao.org/>, accessed July 2012). Countries classified according to WHO regions.

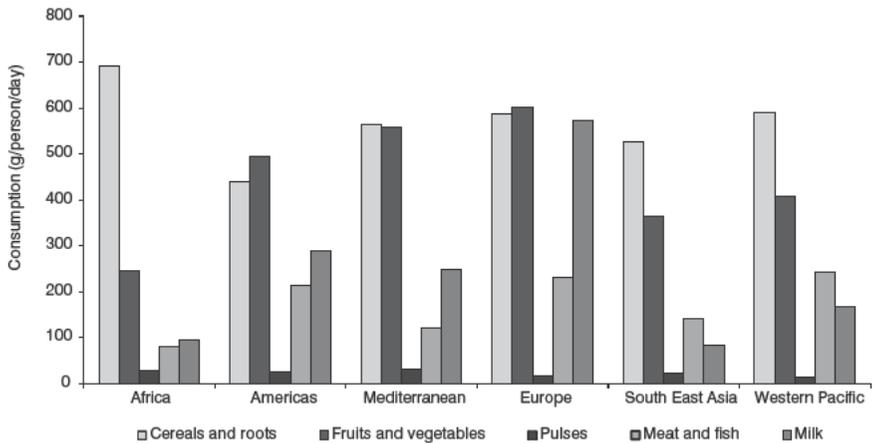


Figure 9.2 Daily consumption of select food groups per person by world region

Note: see footnote to Figure 9.1.

Biodiversity and dietary diversity

At the heart of the biodiversity-for-health position, it is assumed that there is a positive relationship between biodiversity, as manifested in on-farm crop and animal diversity, and dietary diversity. Certainly at some scale, this must be true (if all farmers grew only corn or only rice then there would be little dietary

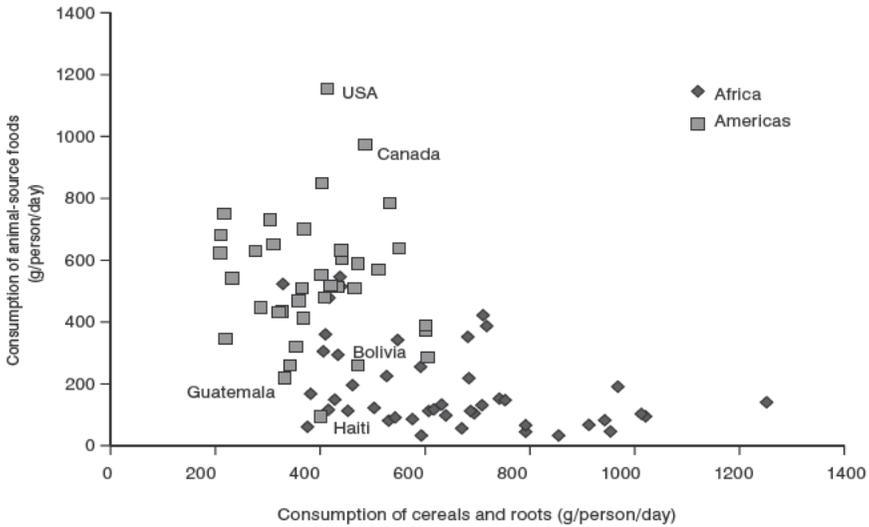


Figure 9.3 Daily consumption of animal-source foods and grains/roots/tubers per person in Africa and the Americas

diversity), but in practice, little evidence exists to support the relationship between biodiversity and household dietary diversity. Evidence from Kenya and Tanzania indicates a positive relationship (Herforth, 2010); however, contradictory evidence from Ecuador shows dietary diversity related to farm size, but not farm diversity (Oyarzun et al., submitted), and a study in Peru showed no relationship between number of varieties grown and child growth or household food security (Scurrah et al., 2011).

Despite the limited evidence, it is posited that biodiversity, in the form of crop diversity and domesticated animal diversity, is a necessary if not sufficient condition for dietary diversity. Presumably there could be increased dietary diversity as more food species and varieties of species are grown, but the magnitude of increased dietary diversity that followed would be a function of the species and varieties introduced. Some varieties of individual crops may be so different from one another as to be considered different foods (Herforth, 2010), such as white- and orange-fleshed sweet potatoes, and therefore variation may be nutritionally meaningful. For other crop varieties, variation may be agronomically meaningful, but nutritionally irrelevant.

If the assumption of a positive relationship between biodiversity and dietary diversity is valid then there are two key (and nuanced) implications for agriculture and nutrition interventions:

- 1 If the distributions of nutrient contents among varieties of most foods are lognormal (or even just positively skewed – see next section) then varieties chosen at random from the distribution of varieties are likely to have nutrient content less than the average, and far less than the maximum.

Likewise, a food chosen at random from the food system (whose distribution is also positively skewed) would exhibit the same pattern. While foods are not chosen at random from food systems, varieties are chosen at random with respect to nutrient content. Varieties may be planted for agronomic, economic, taste, storage or other reasons, but in the absence of a specific nutrition intervention (e.g., a biofortification programme or any intervention that screens and selects varieties based on compositional analysis or traditional knowledge), it is unlikely that the nutrient content of the different varieties will influence cropping decisions. In other words, a highly informed selection process would be required to select a variety with higher-than-average nutrient content. A critical difference, however, is that the high-end of the distribution of foods can be relatively easily selected by a local nutritionist (e.g., most orange-coloured foods have significant quantities of vitamin A activity and most animal-source foods have high levels of iron), whereas such easily applied shortcuts are not available to identify the high-end varieties of a crop (with the exception of the depth of orange colouring indicating vitamin A levels in some foods like orange-fleshed sweet potatoes; Takahata et al., 1993).

- 2 Figure 9.4 shows a scatterplot of quantities of individual food items consumed (g/day) on one day of observation of 20- to 40-year old women in the rural Bolivian Andes by the vitamin A content of the food ($\mu\text{g}/100\text{g}$) (data set described in Berti et al., 2010b).⁴ Five hundred micrograms of

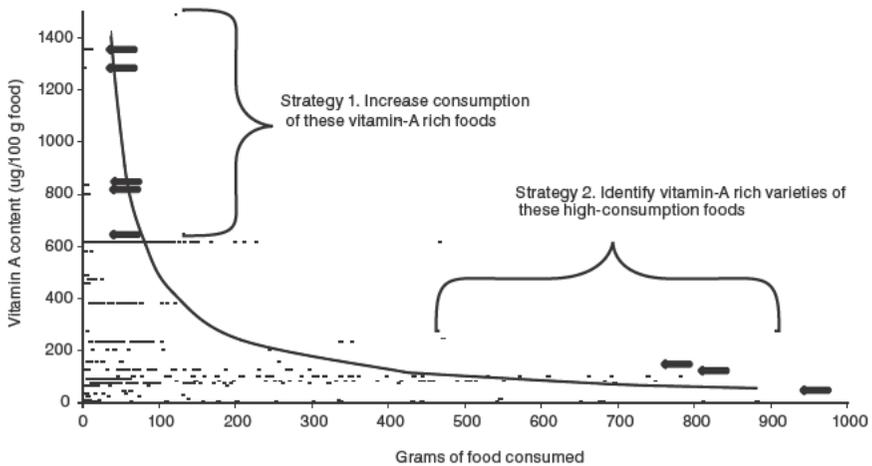


Figure 9.4 Consumption of vitamin A containing foods in women (20–40 yrs) in a rural Bolivian population (3,454 points from 360 women consuming 92 different foods).

Notes: Each point on the graph represents the intersection of the amount of a single food item consumed by a woman on one day and the level of vitamin A in that food. The curved line represents the function of grams of food and vitamin A levels that would provide an intake of 500 μg of vitamin A. 500 μg is the recommended safe intake for adult women (World Health Organization and Food and Agriculture Organization of the United Nations, 2004).

vitamin A is the recommended safe intake for adult women and can serve as a target (daily vitamin A intake will often come from more than one food and so this serves as a guideline, not a prescription). To put more points “above the line”, a strategy may be (1) to increase the consumption of the vitamin A-rich foods (i.e., foods with greater than 600 $\mu\text{g}/100\text{g}$ of vitamin A, of which there are five in this food system) – a conventional “dietary modification” strategy, although also used within biodiversity programmes to promote nutrient-dense, underutilized species within the food system; or (2) to introduce into production varieties of foods that have higher vitamin A levels and are consumed frequently in substantial quantities (e.g., greater than 400 g/day, of which potato is the only example in this population) – a “biodiversity strategy”.

Whether a dietary modification strategy or biodiversity strategy would be appropriate will be situation specific – in this Bolivian setting, dietary modification would be preferred as there are no available vitamin A-rich potato varieties, and even if there were, there are many strong agronomic and cultural reasons for choosing the varieties they do, which would create resistance to changing the varietal mix currently in use. The best candidates for promotion as a vitamin A-rich food already in the diets are carrots and a couple of types of indigenous dark green leafy vegetables – increasing their production is considered feasible by local agronomists and they would be welcomed into their daily meals. There may be other relatively unknown native species and types that would be nutritious and also well suited for cultivation in this environment.

Nutrition and biodiversity

There are many proposed and existing ways to measure biodiversity (Reiss et al., 2009). To quantify the level of biodiversity in a way that is meaningful to human nutrition, there is consideration in the variation in nutrient content of food varieties and within food systems. Many commonly consumed crops have hundreds or thousands of varieties (e.g., more than 100,000 varieties of rice (Sackville Hamilton, 2006) and 4,000 varieties of potato (Burlingame et al., 2009b)), and there are many breeds of domesticated animals (e.g., over 1,000 breeds of sheep and 600 breeds of goats; Jensen, 2009), but only a small fraction of these varieties have nutrient content data available. Additionally there are many underutilized indigenous and wild plants (e.g., Maroyi, 2011; Jeambey et al., 2009; Herforth, 2010), totalling some unknown number of distinct food species, varieties, or breeds. For the vast majority of these there are no nutrient composition data. Therefore, for this chapter, available data are collected on levels of iron and vitamin A (two micronutrients of global public health significance) for specific varieties of various food crops. A similar analysis of less common foods would be desirable but is not currently possible.

Variation in nutrient content between food varieties

Data were available for a number of staple foods (e.g., potato, beans, rice) as well as some less commonly consumed foods (e.g., choysum, strawberries). For some foods, there were many varieties tested (123 varieties of potato, 67 of common bean), and for other foods only a few (four varieties of lentils, six of peas). The minimum and maximum values of vitamin A and iron are shown in Table 9.1. The table includes a variety of food types, including globally important staple foods, common and regional fruits and vegetables. The range in vitamin A is marked, with an over 10,000-fold difference in vitamin A levels between banana varieties, and 100-fold difference for other foods. There is a much lower range in iron levels, with a maximum of a 23-fold difference in iron content between sweet potato varieties, and most of the foods having less than a 5-fold difference between varieties. But even for those foods with small differences (e.g., cassava with 2.5 versus 0.9 mg iron per 100 g) there could still be the difference between sufficiency and insufficiency of the diet (e.g., 400 g of high-iron cassava would meet a five-year-old's iron requirements, but low-iron cassava would supply only one-third of the requirement).⁵

The distribution-fitting function of Crystal Ball (version 11.1, Oracle, Redwood Shores, CA) was used to find the best fitting distributions for those foods with data on ten varieties or more. In general, the data had lognormal distributions, or similar to lognormal distributions (positively skewed, with the mean greater than the median), with SD between one-tenth and three-quarters of the mean (although the strength of the fit to a lognormal distribution was variable, and for some foods, other distributions (normal, gamma, etc.) fit the data more closely). The distribution of iron in 123 potato varieties is shown in Figure 9.5.

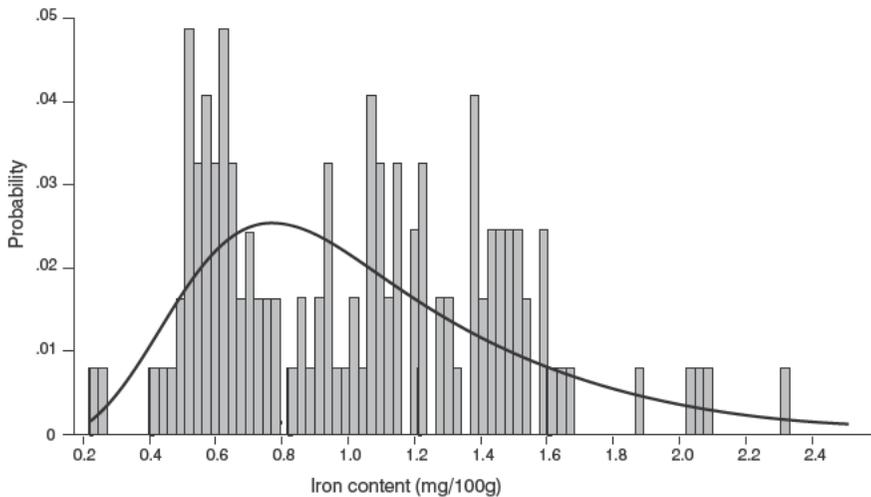


Figure 9.5 Distribution of iron in 123 potato varieties. The bars represent the number of observations at each level. The curve represents a lognormal function fit to the data.

Variation between varieties compared with variation in food systems

To capture the magnitude of interspecies variation within a given food system, there is an evaluation of the iron and vitamin A content in foods in USDA food composition tables (US Department of Agriculture, 2010) – representing perhaps the most variety of any food system in the world – and 92 foods appearing in the diet of a population in rural Bolivia (Berti et al., 2010a; Ministerio de Salud y Deportes, 2005), a diet that is limited in variety and is perhaps typical of diets in low-income countries. Figure 9.6 shows the plotted distribution of iron in the two food systems over the minimum and maximum values from food varieties in Table 9.1. Thus there are two types of distributions with overlapping plots. The bars represent the range of iron content (in mg per 100 g) found in the foods listed on the left vertical axis. The lines represent the distribution of the relative frequency (plotted against the right vertical axis) of iron content in foods in the US and Bolivian food systems. Thus the most common iron content in the USDA and Bolivian food systems is about 1.5 mg per 100 g, but there are some foods with more than 10-fold as much iron per 100 g. The variation in the iron levels is different between crops, with an especially high level of variation in beans and sweet potato. However, this level of variation is less than that found even in the simple Bolivian food system, where 10 per cent of the foods have above 10 mg/100g.

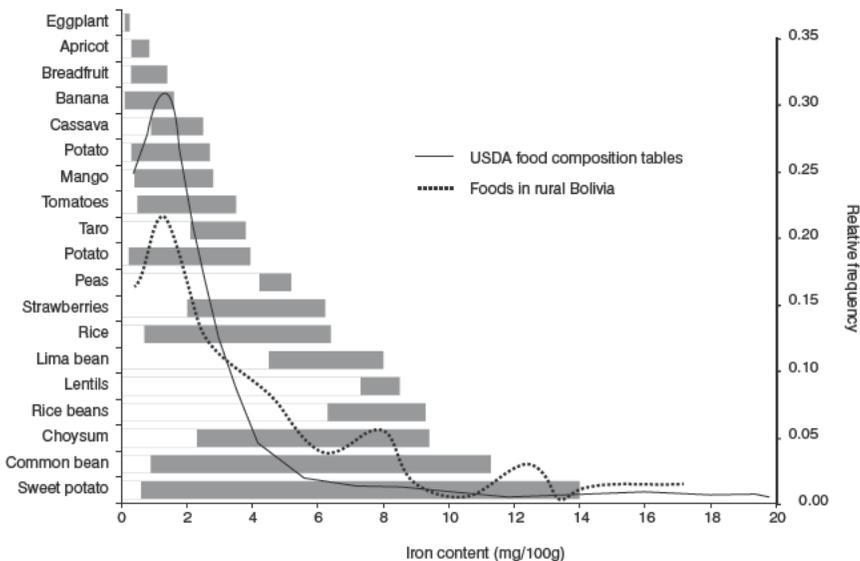


Figure 9.6 Range of iron levels among crop varieties, and relative distribution curves for USDA and rural Bolivian food systems.

Notes: The graph is truncated at 20 mg. USDA foods continue at low frequency to 120 mg. Bolivian foods also include two items > 20 mg: lentils (38 mg) and beef blood (61 mg).

Table 9.1 Minimum and maximum iron levels (mg/100 g raw) and vitamin A levels (retinol equivalents/100 g raw) in selected foods. All vitamin A data are as compiled by Burlingame et al. (2009a), except for pumpkin which is from Murkovic et al. (2002).

Food type	Vitamin A		Iron		n varieties tested ^a	Reference
	Minimum	Maximum	Minimum	Maximum		
Apricot	33	1157	0.3	0.85		Burlingame et al. 2009a
Banana	<1	14167	0.1	1.6		Burlingame et al. 2009a
Breadfruit	1	157	0.29	1.4		Burlingame et al. 2009a
Cassava	1	132	0.9	2.5		Burlingame et al. 2009a
Choysum			2.31	9.4	22	Hanson et al. 2011
Common bean			0.89	11.29	67	de Araujo et al. 2003, Talukder et al. 2010, Barampama and Simard, 1993
Eggplant			0.102	0.247	32	Raigón et al. 2008
Lentils			7.3	8.5	4	Wang and Dean, 2006
Lima bean			4.5	8	18	Ologhobo and Fetuga, 1983
Mango	3	720	0.4	2.8		Burlingame et al. 2009a
Pandanus	2	150				
Peas			4.21	5.19	6	Wang et al. 2008
Potato	<1	1	0.22	3.94	123	Andre et al. 2007, Burgos et al. 2007, Burlingame et al. 2009a
Pumpkin	60	1660				

Rice	15	0.7	6.4	Pereira et al. 2009, Burlingame et al. 2009a
Rice beans	7	6.3	9.3	Kaura and Kapoor, 1992
Strawberries	13	2.01	6.23	Hakala et al. 2003
Sweet potato	17	3850	14	Burlingame et al. 2009a
Taro	1	340	3.8	Burlingame et al. 2009a
Tomatoes	8	0.49	3.5	Guil-Guerrero and Reboloso-Fuentes, 2009

Note

a Number of varieties tested not listed in Burlingame et al. (2009a).

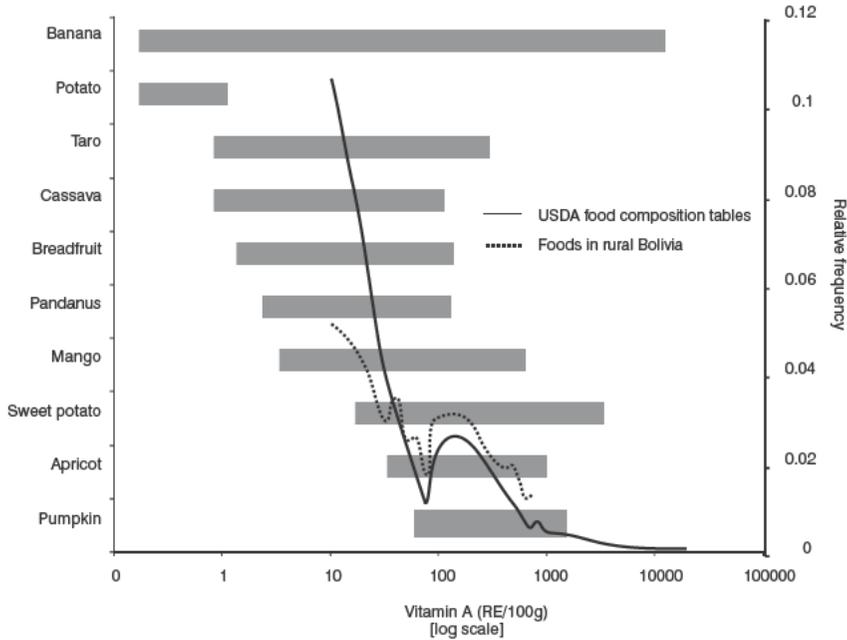


Figure 9.7 Range of vitamin A levels among crop varieties, and relative distribution curves for USDA and rural Bolivian food systems.

Note: 41 per cent of USDA foods have 0 vitamin A and 15 per cent have < 5 RAE. 52 per cent of Bolivian foods have 0 vitamin A and 4 per cent have < 5 RAE. These figures are not shown in the graph.

Figure 9.7 is similar to Figure 9.6, summarizing the levels of vitamin A in varieties of different crops, as well as in the food systems of the US and rural Bolivian population. As with the example of iron, the USDA data represents a food system with great variety, and the Bolivian food system has minimal variety.

Conclusion

Drawing from various data sources, we have considered biodiversity from a nutrition perspective, particularly regarding its link to dietary diversity. If an agricultural intervention aims to introduce a new food crop or animal to increase dietary diversity and nutrient intake, then the analyses summarized in Figures 9.6 and 9.7 suggest that there are more potential foods to be found through considering the entire food system rather than just varieties of a single food (Strategy 1 of Figure 9.4). As summarized in the discussion of Figure 9.4, however, this will be context specific. Another important advantage of prioritizing the diversity of food systems is that high-nutrient content foods can be identified by any locally trained nutritionist (e.g., carrots, mangos and papayas are all high in β -carotene; lentils, soybeans and all meats are high in iron)



Figure 9.8 Harvested maize stored at a local homestead in northern Potosí, Bolivia. Photograph by Andrew Jones

without difficult analysis of varieties. However, in some settings, it may be easier to identify or develop varieties of staples that are rich in micronutrients than it would be to increase consumption of non-staple, micronutrient-rich crops (Strategy 2 of Figure 9.4). This strategy has not been explicitly tested though and trials comparing the effectiveness of “Strategy 1” and “Strategy 2” are needed.

This chapter concludes with a series of questions that should be considered, regardless of the strategy envisioned. These questions have direct nutrition consequences for participating farming households, but may not normally be asked prior to an agriculture–nutrition intervention.

- 1 What is the problem that needs to be addressed? Are there specific nutrient deficiencies?
- 2 Are there priority nutrition problems that have been identified that justify carrying out any sort of intervention? Could these problems possibly be addressed through food-based interventions? Whose needs will be met through the intervention?
- 3 How will a new variety ultimately be used? And who controls decisions of use and the benefits of that end use?
- 4 Will the crop be consumed by the farming household? If it is sold, will it be sold locally, benefiting other local families or will it supply the export market? If sold, who will control the earned income?⁶
- 5 Will the variety displace micronutrient-dense crops, be introduced on pastureland that is used to raise animals and provide meat, milk or eggs for the family, or displace other plants or animals with biodiversity importance? Or will it replace less desirable crops?



Figure 9.9 A field of Andean lupine, known locally as “tarwi”, in northern Potosí, Bolivia. Photograph by Andrew Jones

- 6 It is possible that a crop is introduced for biodiversity reasons, but then the market for it expands and the acreage for this introduced crop increases and ultimately reduces on-farm biodiversity.
- 7 Will the new variety fill gaps in seasonal food supplies?
- 8 Will it be late maturing, early maturing, could it be harvested at multiple times throughout the year? Will it store well?
- 9 What is the pattern of food distribution within the household? Will the new variety be a preferred food among all family members? Will specific efforts be required to promote consumption by children?
- 10 How will the new variety affect time allocation, particularly for women?
- 11 If the new variety leads to more work for women and this is not managed properly, it could lead to less time for child feeding (especially breastfeeding), child care and ultimately poorer health outcomes.
- 12 Are there any safety issues associated with the new species or variety?
- 13 Are there disease vectors associated with the species? Is pesticide use expected? Does the culture have a practice of safely preparing the species or variety for consumption?

These questions are not new, but there is a different dimension when they are addressed from biodiversity and dietary diversity points of view. As programmes in biodiversity and dietary diversity increasingly overlap and, hopefully, mutually reinforce each other, the experiences of the practitioners and their answers to these questions should be documented and disseminated to improve future efforts.

Notes

- 1 For example, 15 different foods had high sensitivity to identify nutritionally inadequate diets as inadequate among preschool-aged children in urban Mali (Hatløy et al., 1998), but only six different foods were required to achieve both high sensitivity and specificity for dietary adequacy among a nationally representative sample of South African children (Steyn et al., 2006). Likewise, dietary diversity indices that appropriately select cut off points based on the internal distribution of the diversity indicator within their sample (Moursi et al., 2009; Ruel and Menon, 2002) are not able to generalize those cut offs to populations outside those from which data were collected.
- 2 One study did fail to show a positive association between dietary diversity and nutrient intakes (Ferguson et al., 1993). In one study that compared individual foods and food groups, though both were associated with dietary adequacy, consumption of a greater diversity of food groups was a stronger determinant of dietary adequacy than consuming a larger diversity of individual foods (Hatløy et al., 1998). In two other studies that measured both indicators, the relative strength of individual foods versus food groups in predicting dietary adequacy was less clear (Steyn et al., 2006; Torheim et al., 2004), though Torheim and others found that a food variety score contributed more significantly to regression model variation than a food group score.
- 3 Though diets high in fat and dietary cholesterol are associated with higher risk of chronic disease (American Heart Association, 1996; Oh et al., 2005) animal-source foods are an excellent source of bioavailable micronutrients, such as iron, zinc and vitamin A, that are often lacking in diets in low-income countries, and are particularly important for proper child growth (Penny et al., 2005).
- 4 Note that the data collection and analysis tools used tended to group foods together (e.g., perhaps five to ten types of potatoes were all commonly eaten, but all were grouped as one general type, "potato"). This reduces the apparent variation that exists in the diet, and in Figure 9.4, and so the figure should be considered for illustration of the concept, but as a simplified presentation of the real situation.
- 5 $400 \text{ g} \times 2.5 \text{ mg}/100 \text{ g} = 10 \text{ mg}$, which is the EAR (estimated average requirement) of iron, for a low bioavailability diet.
- 6 Control of new income within households will no doubt determine in part the extent to which increased incomes lead to more diverse diets and improved health outcomes for family members. Strong evidence from many different regions suggests that income controlled by women benefits child nutrition and household food security to a greater extent than income controlled by men (Quisumbing et al., 1995; Kennedy and Cogill, 1987).

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