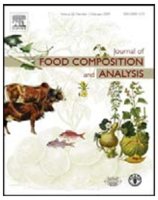
Journal of Food Composition and Analysis 22 (2009) 361–365

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca



Study review

Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition

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ARTICLE INFO

Article history:
Received 30 March 2009
Received in revised form 28 May 2009
Accepted 28 May 2009

Keywords:
Food composition databases
Data compilation
Food database management
Cultivar influence on nutrient intake
Varieties, cultivars, landraces
Biodiversity
Nutrition
Agriculture
Cross-cutting initiative on biodiversity for food and nutrition
Bioversity International
FAO
Convention on Biological Diversity (CBD)
Food composition

ABSTRACT

The usefulness of food composition data at the level of the genetic resource (i.e. taxonomic level below species) is becoming increasingly acknowledged. Recent research has provided data to confirm the micronutrient superiority of some lesser-known cultivars and wild varieties over other, more extensively utilized cultivars. Sweet potato cultivars have been shown to differ in their carotenoid content by two orders of magnitude or more; protein content of rice varieties can range from 5 to 13%; provitamin-A carotenoid content of bananas can be less than 1 mcg/100 g for some cultivars to as high as 8500 mcg/100 g for other cultivars. Intake of one variety rather than another can be the difference between micronutrient deficiency and micronutrient adequacy. These data are important for the sectors of health, agriculture, trade and the environment. The importance of nutrition is now recognized by the Convention on Biological Diversity (CBD) and the Commission on Genetic Resources for Food and Agriculture. At the request of the CBD, FAO is leading the "Cross-cutting initiative on biodiversity for food and nutrition," in collaboration with Bioversity International, and developing or improving compositional databases will form a significant part of the initiative. Once the data are prepared and compiled, they can be used in practically every domain of nutrition: nutrition education, community nutrition, nutrition interventions, food emergencies, nutritional labelling, food consumption surveys, to name but a few. These data should be "mainstreamed" into national and regional food composition databases giving recognition and importance to cultivars, varieties and breeds as foods in their own right.

Contents

1. Introduction

Over 7000 plant species have been cultivated for food, yet it is estimated that 90% of the world's dietary energy supply is obtained from only 30 species (FAO, 1997). Thousands of species, and many more varieties, fall into a category defined as underutilized or neglected crops. These crops are marginalized by both agriculture and nutrition researchers (Global Forum for Underutilized Species, 2009). Economics and production or trade volumes are among the driving forces for monoculture agriculture. In food composition work, most protocols for sampling, analyzing and compiling data use composite food samples, masking the nutrient variability inherent within and among species.

Many factors are known to affect the nutrient content of foods, including climate (Rodriguez-Amaya et al., 2008), geography and geochemistry (Nordbotten et al., 2000; Nikkarinen and Mertanen,

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doi:10.1016/j.jfca.2009.05.003

2004; Wall, 2006), agricultural practices such as fertilizer use (Mercadante and Rodriguez-Amaya, 1991), stage of maturity (Río Segade et al., 2008) the growth period (Huang et al., 2007; Rodriguez-Amaya et al., 2008) and variation due to differences in nutrient composition of foods below the level of species, i.e. subspecies, variety, cultivar or breed (Toledo and Burlingame, 2006a). In the past, generic food composition data were considered sufficient for most purposes and were regarded as high-quality data when they represented "year-round, nation-wide means" (Greenfield and Southgate, 2003). This approach intentionally obscured variations in composition that might have been systematic and notable. More recently, the importance of differentiating foods at the level of species and below has been documented through compositional research (Toledo and Burlingame, 2006b).

Although important for all food composition work, using quality control materials and reporting the results are vital for work related to biodiversity, so that variability due to methodology may be separated from biological variability. And even more importantly, the minimum number of independent samples analyzed should be greater than in other food composition projects in order to separate differences among varieties versus inherent differences within varieties.

From the nutrition perspective, a myriad of different food species, and varieties within species, are consumed in traditional diets, providing energy and nutrients, and thus contributing to food and nutrition security (Toledo and Burlingame, 2006a). Due to the lack of professional attention to biodiversity and underutilized foods, large gaps exist in our knowledge of the composition and the dietary contribution of these foods to human nutrition. This has been an area neglected, or regarded as unimportant, by compilers of food composition databases and investigators involved in designing and executing food consumption surveys (Burlingame, 2004). Therefore, the real and potential contribution of these foods to nutrition and health improvements cannot be judged. Data on nutrients, bioactive non-nutrients and antinutrients are lacking for many food species (Kuhnlein, 2003; Rodriguez-Amaya et al., 2008), and are even fewer for varieties, cultivar, and breeds within species. On the dietary consumption side, there are often errors in accurately recording generic foods consumed, especially of fruits, fish, vegetable and other non-staples (Pomerleau et al., 2003), and considerable lack of attention to the identification of below-species level (Kennedy and Burlingame, 2003).

Data on the nutrient content of foods at the level of the genetic resource are important for the sectors of health, agriculture, trade and the environment. In agriculture, information on cultivar-specific composition can be used in breeding programs to enhance the nutrient content of more commonly used varieties of the same species, eliminating the need for transgenic modifications and their associated difficulties (Ramessar et al., 2009). In trade, absence of cultivar-specific food composition data can constitute a technical barrier to trade, as most potential export markets for unique species and cultivars require or encourage nutrient composition data for labels and point-of-purchase materials. And for the environment sector, knowledge of nutrients and other bioactive components helps to reassess the value of neglected varieties, encouraging their sustainable use (Toledo and Burlingame, 2006a; CBD, 2004).

The Expert Consultation on Nutrition Indicators for Biodiversity held in October 2007 (FAO, 2008) developed a food composition indicator for biodiversity and nutrition to measure the progress that has been made in availability of compositional data on biodiversity by counting the number of foods with a sufficiently detailed description (mostly below-species level: subspecies, variety, cultivar, and breed) and with at least one value for a nutrient or other bioactive component. The indicator will be based on well-documented literature, including national, regional or international food composition databases and scientific literature. A regular reporting on the progress will be carried out through the INFOODS (2008) Regional Data Centre Coordinators, FAO and others. Another expert consultation meeting is planned for 2009 to develop a food consumption indicator for biodiversity and nutrition.

All these compositional data-related activities, along with dissemination in many forms and mainstreaming in the health, agriculture and environments sectors, form a substantial part of the cross-cutting initiative on biodiversity for food and nutrition.

2. Differences in nutrient values for the same species and application of results

The compositional differences among varieties or cultivars can be very significant for macronutrients, micronutrients and bioactive non-nutrients. Table 1 shows some selected foods and components demonstrating the range of nutrient values. It is generally thought that macronutrients vary only insignificantly within the same species (Greenfield and Southgate, 2003, p. 74). However, data show that this is not always the case. Among rice varieties, protein content can vary from 5.6% to 14.6%, representing a highly significant difference, not only just statistically, but also nutritionally. For many crops within the same species micronutrient contents of different varieties can have much wider ranges. Varietal differences in beta-carotene can vary by three orders of magnitude or more. For example, some banana varieties provide less than 1 mcg/100 g of beta-carotene, while others can provide as much as 8500 mcg/100 g. These differences in nutrients among cultivars have a major impact on nutrient intake estimations, to the extent that intake of one variety versus another can be the difference between micronutrient deficiency and micronutrient adequacy. For this reason, the cross-cutting initiative is addressing both composition and consumption.

2.1. Rice

The International Rice Commission (IRC) has recognized differences in the composition of rice varieties and their contributions to nutrient intakes. During the last two sessions of the IRC, the following was reported (FAO, 2002; Kennedy et al., 2003):

- Wild species and intraspecies biodiversity play key roles in global food security.
- Different varieties demonstrate statistically different nutrient contents.
- Acquiring nutrient data on existing biodiversity needs to be a prerequisite for decision-making in GMO work.
- Nutrient content should be included among criteria in cultivar promotion.

2.2. Root and tuber crops

Although a wide range of tuber crops are grown worldwide, only five species account for the majority of the total world production: potato (*Solanum tuberosum*), cassava (*Manihot esculenta*), sweet potato (*Ipomea batatas*), yams (*Dioscorea* spp.) and taro (*Colocassia*, *Cytosperma*, *Xanthosoma* spp.) (O'Hair and Maynard, 2003; Maynard and O'Hair, 2003). Root and tuber crops are staple foods in many countries and are considered a good and inexpensive source of energy and carbohydrate in the diets. Recent studies on varieties of cassava, sweet potato and yam show that there are great differences in nutrient content within species, and that some varieties can provide a substantial contribution to

Table 1
Examples of nutrient composition within varieties (per 100 g edible portion, raw).

	Protein, g	Fibre, g	Iron, mg	Vitamin C, mg	Beta-carotene, mcg	References
Rice	5.6–14.6		0.7–6.4			Kennedy and Burlingame (2003)
Cassava	0.7–6.4	0.9–1.5	0.9–2.5	25–34	<5–790	Ceballos et al. (2006), Charles et al. (2005), Chávez et al. (2005), Food composition and nutrition tables (Germany), 2000, Kimura et al. (2007), Kumar and Aalbersberg (2006a,b), Moorthy et al. (1990), Roy and Chakrabarti (2003), Ayankunbi et al. (1991) and Ekpenyong (1984)
Potato	1.4–2.9	1–2.29	0.3–2.7	6.4–36.9	1–7.7	Burgos et al. (in press), Food composition and nutrition tables (Germany), 2000, Warman and Havard (1998), Hajšlová et al. (2005) and McCance and Widdowson's (2002)
Sweet potato	1.3–2.1	0.7–3.9	0.6–14	2.4–35	100–23100	Huang et al. (1999), USDA (2007), Bovell-Benjamin (2007), Kidmose et al. (2007), Olaofe and Sanni (1988), Wu et al. (2008), Ishida et al. (2000) and Van Jaarsveld et al. (2006)
Taro	1.1–3	2.1–3.8	0.6–3.6	0–15	5–2040	Huang et al. (2000), Kumar and Aalbersberg (2006a,b) and Englberger et al. (2003a, 2008)
Breadfruit	0.7–3.8	0.9	0.29–1.4	21–34.4	8–940	Huang et al. (2000), Englberger et al. (2003b) and Ragone (2003)
Eggplant		9–19		50–129		Hanson et al. (2006)
Mango	0.3–1.0	1.3–3.8	0.4–2.8	22–110	20–4320	Rodriguez-Amaya (1997), Ramulu and Udayasekhara Rao (2003), Hernández et al. (2006) and Favier et al. (1993)
Banana			0.1–1.6	2.5–17.5	<1–8500	Englberger et al. (2003c), Philippine Food composition tables (1997), Wall (2006) and Aremu and Udoessien (1990)
Pandanus			0.4	5–10	14–902	Englberger et al. (2006a,b)
GAC					6180–13720	Vuong et al. (2006)
Apricot	0.8–1.4	1.7–2.5	0.3–0.85	3.5–16.5	200–6939 (beta-carotene equivalent)	Food composition and nutrition tables (Germany), 2000, McCance and Widdowson's (2002), NUTTAB (2006), Athar et al. (2003) and USDA (2007)

nutritional requirements, not only for energy but also for protein and micronutrients (see Table 1). It should be noted that antinutrients, e.g. cyanogenic compounds in cassava, also vary considerably among varieties within the same species (Hidayat et al., 2000).

For the sweet potato (*Ipomea batatas*), nutrient content can vary greatly depending on the cultivar (see Table 1). As an example, orange-fleshed sweet potatoes are exceptional sources of provitamin A and play a significant role in preventing vitamin A deficiency (Van Jaarsveld et al., 2005, 2006; Kidmose et al., 2007). Huang et al. (1999) reported Pacific Island sweet potato varietal differences in alpha- and beta-carotene of nearly two orders of magnitude. This same report showed that the low-carotene sweet potatoes were much more likely to be promoted to farmers by the agriculture extension workers, rather than the high carotene varieties, mainly for their greater yield and better disease resistance.

2.3. Fruits—mango and bananas

Sixty-nine *Mangifera* species and several hundred cultivars have been identified, most of which belong to the species *Mangifera indica* (Rao and Bhag, 2002). Colour gives evidence of the nutritionally significant differences in beta-carotene content of different varieties. However, food composition tables and databases generally show only one or a few entries for mango; e.g. the Indian food composition table (Gopalan et al., 1982) reports only "Ripe Mango" while nearly one thousand local varieties have been characterized.

An important initiative has been undertaken by researchers in Micronesia to document the carotenoid composition of traditional banana species and varieties. Eight were found to have beta-carotene levels greater than 525 mcg/100 g edible portion, which is 25 times the beta-carotene level reported for varieties analyzed in the United States and England. One variety contains more than 8000 mcg/100 g. Were this underutilized food resource to be used, it could supply much of the daily vitamin A requirements for children and adults (Englberger et al., 2003a) in the four island states of the Federated States of Micronesia where vitamin A deficiency persists as a significant problem (Centers for Disease Control and Prevention, 2001).

3. Food biodiversity as an ecosystem service

The types and amounts of food produced in rice-based aquatic ecosystems (other than rice itself) are generally underestimated, undervalued or not recorded in official statistics. They include finfish, shellfish, other aquatic animals, and leafy green vegetables. These organisms supply nutrients to the diet that are limited or absent in rice, such as calcium, iron, zinc, vitamin A, high-quality protein and amino acids, fatty acids and other nutrients.

Recent studies in Cambodia, China, Laos and Vietnam provided information and data on aquatic biodiversity and the contribution these resources make to rural livelihoods, food security and nutrition. These studies have documented the presence of 145 finfish species, 11 crustaceans, 15 molluscs, 13 reptiles, 11 amphibians, 11 insects and 37 plants collected from the rice fields and utilized by rural people during one season (Halwart and Bartley, 2005). A recent consumption study in Laos (FAO/LARReC, 2007) has been undertaken in an attempt to create a suitable methodology to collect data on fish catch and consumption; it showed that rice fields are the source of about two-thirds of all aquatic organisms consumed by rural households. The official Lao Government data state that the annual fish consumption per person is about 25 kg/cap/year, while this study showed an annual fish consumption of nearly 50 kg/cap/year and of other aquatic organisms of nearly 100 kg/cap/year. However, compositional data of these fish species and other aquatic organisms are limited or absent altogether. Thus, the nutritional importance of biodiversity from rice-based ecosystems cannot as yet be properly assessed (Halwart, 2006).

In many parts of the world, with efforts to intensify agricultural production, and because of other ecosystem pressures, diversity is decreasing dramatically and eliminating essential sources of food and nutrients for rural people.

4. Conclusions

From the viewpoint of the environment sector, the ultimate goal of the cross-cutting initiative is the conservation and sustainable use of biodiversity. From the viewpoint of the nutrition sector (both health and agriculture), the ultimate goal of the initiative is food and nutrition security. In combination, the synergies of different sectors can and should lead to healthier populations and healthier ecosystems.

Food composition activities continue to improve the evidence base, which in turn gives value to ecosystems, the food species they contain, and the within-species diversity. In food- and nutrition-insecure populations, intake of one variety rather than another can be the difference between micronutrient deficiency and micronutrient adequacy. Still more effort and resources are needed to analyze, compile and disseminate data on the nutrient composition of wild, underutilized, and under-appreciated food biodiversity. The availability of these data will assist countries to promote local species and varieties and to value and maintain the ecosystems that produce them. This is the essence of the cross-cutting initiative on biodiversity for food and nutrition.

References

Aremu, C.Y., Udoessien, E.I., 1990. Chemical estimation of some inorganic elements in selected tropical fruits and vegetables. Food Chemistry 37, 229–234.

Athar, N., McLaughlin, J., Taylor, G., 2003. The Concise New Zealand Food Composition Tables, 6th edition. New Zealand Institute for Crop and Food Research, Crown Research Institute.

Ayankunbi, M.A., Keshinro, O.O., Egele, P., 1991. Effect of methods of preparation on the nutrient composition of some cassava products—Garri (eba), 'Lafun' and 'Fufu'. Food Chemistry 41, 349–354.

Bovell-Benjamin, A.C., 2007. Sweet potato: a review of its past, present, and future role in human nutrition. Advances in Food and Nutrition Research 52, 1–59.

Burgos, G., Auqui, S., Amoros, W., Salas, E., Bonierbale M., in press. Ascorbic acid concentration of native Andean potato varieties as affected by environment, cooking and storage. Journal of Food Composition and Analysis. Available online 29 August 2008, doi:10.1016/j.jfca.2008.05.013.

Burlingame, B., 2004. Fostering quality data in food composition databases: visions for the future. Journal of Food Composition and Analysis 17 (3–4), 251–258.

CBD, 2004. Seventh Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 7), Decision VII/32, The Programme of Work of the Convention and the Millennium Development Goals. Retrieved 2006-03-13: http://www.biodiv.org/decisions/default.aspx?m=COP-07&id=7769&lg=0.

CDC, 2001. Vitamin A Deficiency Among Children—Federated States of Micronesia, 2000. Morbidity and Mortality Weekly Report June 22, 2001/50(24), 509–512

Ceballos, H., Sánchez, T., Chávez, A.L., Iglesias, C., Debouck, D., Mafla, G., Tohme, J., 2006. Variation in crude protein content in cassava (*Manihot esculenta* Crantz) roots. Journal of Food Composition and Analysis 19, 589–593.

Charles, A.L., Sriroth, K., Huang, T., 2005. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. Food Chemistry 92, 615–620.

Chávez, A.L., Sánchez, T., Jaramillo, G., Bedoya, J.M., Echeverry, J., Bolaños, E.A., Ceballos, H., Iglesias, C.A., 2005. Variation of quality traits in cassava roots evaluated in landraces and improved clones. Euphytica 143, 125–133.

Ekpenyong, T.E., 1984. Composition of some tropical tuberous foods. Food Chemistry 15, 31–36.

Englberger, L., Aalbersberg, W., Fitzgerald, M., Marks, G., Chand, K., 2003a. Provitamin A carotenoid content of different cultivars of edible pandanus fruit. Journal of Food Composition and Analysis 16, 237–247.

Englberger, L., Aalbersberg, W., Ravi, P., Bonnin, E., Marks, G.C., Fitzgerald, M.H., Elymore, J., 2003b. Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals. Journal of Food Composition and Analysis 16, 219–236.

Englberger, L., Schierle, J., Marks, G., Fitzgerald, M., 2003c. Micronesian banana, taro and other foods: newly recognized sources of provitamin A and other carotenoids. Journal of Food Composition and Analysis 16, 3–19.

Englberger, L., Aalbersberg, W., Schierle, J., Marks, G.C., Fitzgerald, M.H., Muller, F., Jekkein, A., Alfred, J., Vander Velde, N., 2006a. Carotenoid content of different edible pandanus fruit cultivars of the Republic of the Marshall Islands. Journal of Food Composition and Analysis 19, 484–494.

Englberger, L., Aalbersberg, W., Dolodolotawake, U., Schierle, J., Humphries, J., Luta, T., Marks, G.C., Fitzgerald, M.H., Rimon, B., Kaiririete, M., 2006b. Carotenoid content of pandanus fruit cultivars and other foods of the Republic of Kiribati. Public Health Nutrition 9, 631–643.

Englberger, L., Schierle, J., Kraemer, K., Aalbersberg, W., Dolodolotawake, U., Humphries, J., Graham, R., Reid, A.P., Lorens, A., Albert, K., Levendusky, A., Johnson, E., Paul, Y., Sengebau, F., 2008. Carotenoid and mineral content of Micronesian giant swamp taro (Cyrtosperma) cultivars. Journal of Food Composition and Analysis 21, 93–106.

FAO, 1997. State of the world's plant genetic resources for food and agriculture. FAO, Rome.

FAO, 2002. Major Recommendations of the 20th Session of the International Rice Commission, 23–26 July 2002, Bangkok, Thailand. Retrieved 2006-03-13: http://www.fao.org/ag/agp/agpc/doc/field/commrice/pages/sessions.html#01.

FAO, 2008. Expert consultation on nutrition indicators for biodiversity—1. In: Food Composition, FAO, Rome.

FAO/LARReC, 2007. Aquatic biodiversity in rice-based ecosystems for Lao PDR. Technical Paper. FAO—Netherlands Partnership Programme (FNPP) 2006–2007 (unpublished).

Favier, J.C., Ireland-Ripert, J., Laussucq, C., Feinberg, M., 1993. CIQUAL, CNEVA: Table de composition des fruits exotiques, fruits de ceuillette d'Afrique. ORSTOM editions, Lavoisier, INRA editions.

Food Composition And Nutrition Tables (Germany, 6th edition) (2000). On behalf of the Bundesministerium für Ernährung, Landwirtschaft und Forsten, Bonn; edited by Deutsche Forschungsanstalt für Lebensmittelchemie, Garching b. München=Die Zusammensetzung der Lebensmittel Nährwert-Tabellen.

Food and Nutrition Research Institute, 1997. The Philippine Food Composition Tables. Department of Science and Technology, Manila.

Global Forum for Underutilized Species, 2009. http://www.underutilized-species.org/about_GFU.asp (accessed 04.05.09.).

Gopalan, C., Rama Sastri, B.V., Balasubramanian, S.C., 1982. Nutritive Value of Indian Foods. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad; New Delhi.

Greenfield, H., Southgate, D.A.T., 2003. Food Composition Data: Production, Management and Use. FAO, Rome.

Hajšlová, J., Schulzová, V., Slanina, P., Janné, K., Hellenäs, K.E., Andersson, C.H., 2005. Quality of organically and conventionally grown potatoes: four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. Food Additives and Contaminants 22, 514–534.

Halwart, M., 2006. Biodiversity and nutrition in rice-based aquatic ecosystems. Journal of Food Composition and Analysis 19, 747–751.

Halwart, M., Bartley, D. (Eds.), 2005. Aquatic Biodiversity in Ricebased Ecosystems. Studies and Reports from Cambodia, China, Lao PDR and Viet Nam. FAO, Rome. , In: ftp://ftp.fao.org/FI/CDrom/AqBiodCD20Jul2005/Start.pdf.

Hanson, P.M., Yang, R.Y., Tsou, S.C.S., Ledesmaa, D., Engle, L., Leeb, T.-C., 2006. Diversity in eggplant (*Solanum melongena*) for superoxide scavenging activity, total phenolics and ascorbic acid. Journal of Food Composition and Analysis 19, 594–600.

Hernández, Y., Lobo, M.G., González, M., 2006. Determination of vitamin C in tropical fruits: a comparative evaluation of methods. Food Chemistry 96, 654–664.

Hidayat, A., Zuaraida, N., Hanarida, I., Damardjati, D.S., 2000. Cyanogenic content of cassava root of 179 cultivars grown in Indonesia. Journal of Food Composition and Analysis 13 (1), 71–82.

Huang, A.S., Tanudjaja, L., Lum, D., 1999. Content of alpha-, beta-carotene, and dietary fiber in 18 sweetpotato varieties grown in Hawaii. Journal of Food Composition and Analysis 12, 147–151.

Huang, A.S., Titchenal, C.A., Meilleur, B.A., 2000. Nutrient composition of taro corms and breadfruit. Journal of Food Composition and Analysis 13, 859–864.

Huang, C.C., Chiang, P.Y., Chen, Y.Y., Wang, C.C.R., 2007. Chemical compositions and enzyme activity changes occurring in yam (*Dioscorea alata* L.) tubers during growth. LWT—Food Science and Technology 40, 1498–1506.

INFOODS, 2008. The International Network of Food Data Systems. Retrieved 2008-07-20: http://www.fao.org/infoods/.

Ishida, H., Suzuno, H., Sugiyama, N., Innami, S., Tadokoro, T., Maekawa, A., 2000. Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes (*Ipomoea batatas* poir). Food Chemistry 68, 359–367.

Kennedy, G., Burlingame, B., 2003. Analysis of food composition data on rice from a plant genetic resources perspective. Food Chemistry 80, 589–596.

Kennedy, G., Burlingame, B., Nguyen, V.N., 2003. Nutritional contribution of rice and impact of biotechnology and biodiversity in rice-consuming countries. In: Proceedings of the 20th Session of the International Rice Commission, Bangkok, Thailand, FAO, Rome, pp. 59–69.

Kidmose, U., Christensen, L.P., Agili, S.M., Thilsted, S.H., 2007. Effect of home preparation practices on the content of provitamin A carotenoids in coloured sweet potato varieties (*Ipomoea batatas* Lam.) from Kenya innovative. Food Science and Emerging Technologies 8, 399–406.

Kimura, M., Kobori, C.N., Rodriguez-Amaya, D.B., Nestel, P., 2007. Screening and HPLC methods for carotenoids in sweetpotato cassava and maize for plant breeding trials. Food Chemistry 100, 1734–1746.

Kuhnlein, H., 2003. Micronutrient nutrition and traditional food systems of indigenous peoples. Journal of Food Nutrition and Agriculture 32, 33–37.

Kumar, S., Aalbersberg, B., 2006a. Nutrient retention in foods after earth-oven cooking compared to other forms of domestic cooking: 1. Proximates, carbohydrates and dietary fibre. Journal of Food Composition and Analysis 19, 302–310.

Kumar, S., Aalbersberg, B., 2006b. Nutrient retention in foods after earth-oven cooking compared to other forms of domestic cooking 2. Vitamins. Journal of Food Composition and Analysis 19, 311–320.

Maynard, D.N., O'Hair, S.K., 2003. Vegetables of tropical climates. In: Root Crops of Lowlands Encyclopedia of Food Sciences and Nutrition, pp. 5965–5970.

McCance, Widdowson's, 2002. The Composition of Foods, 6th Summary edition. Food Standards Agency and Institute of Food Research, Royal Society of Chemistry, Cambridge.

Mercadante, A.Z., Rodriguez-Amaya, D.B., 1991. Carotenoid composition of a leafy vegetable in relation to some agricultural variables. Journal of Agricultural and Food Chemistry 39, 1094–1097.

Moorthy, S.N., Jos, J.S., Nair, R.B., Sreekumari, M.T., 1990. Variability of β-carotene content in cassava germplasm. Food Chemistry 36, 233–236.

Nikkarinen, M., Mertanen, E., 2004. Impact of geological origin on trace element composition of edible mushrooms. Journal of Food Composition and Analysis 17, 301–310.

Nordbotten, A., Løken, E.B., Rimestad, A.H., 2000. Sampling of potatoes to determine representative values for nutrient content in a national food composition table. Journal of Food Composition and Analysis 13, 369–377.

NUTTAB, 2006. Australian Food Composition Tables. http://www.foodstandards.gov.au/monitoringandsurveillance/nuttab2006/index.cfm.

O'Hair, S.K., Maynard, D.N., 2003. Vegetables of tropical climates. In: Root Crops of Uplands Encyclopedia of Food Sciences and Nutrition, pp. 5962–5965.

Olaofe, O., Sanni, C.O., 1988. Mineral contents of agricultural products. Food Chemistry 30, 73–77.

Pomerleau, J., Lock, K., Mc Kee, M., 2003. Discrepancies between ecological and individual data on fruit and vegetable consumption in fifteen countries. Journal of Nutrition 89, 827–834.

Ragone, D., 2003. Breadfruit Encyclopedia of Food Sciences and Nutrition. , pp. 655–661.

Ramessar, K., Capell, T., Twyman, R.M., Quemada, H., Christou, P., 2009. Calling the tunes on transgenic crops: the case for regulatory harmony. Molecular Breeding 23 (1), 99–112.

Ramulu, P., Udayasekhara Rao, P., 2003. Total, insoluble and soluble dietary fiber contents of Indian fruits. Journal of Food Composition and Analysis 16, 677–685.

Rao, R., Bhag, M., 2002. Tropical fruit species in Asia: diversity and conservation strategies, pp. 179–190. In: R. Drew (Ed.), Proceedings of the International Symposium on Tropical and Sub-tropical fruits. Acta Horticulturae 575.

Río Segade, S., Soto Vázquez, E., Díaz Losada, E., 2008. Influence of ripeness grade on accumulation and extractability of grape skin anthocyanins in different cultivars. Journal of Food Composition and Analysis 21, 599–607.

Rodriguez-Amaya, D.B., 1997. Carotenoids and food preparation: the retention of provitamin A carotenoids in prepared, processed and stored foods. Office of Health & Nutrition, Bureau for Global Programmes, US Agency for International Development, John Snow, Inc/OMNI Project. 88 pp. (English).

Rodriguez-Amaya, D.B., Kimura, M., Godoy, H.T., Amaya-Farfan, J., 2008. Updated Brazilian database on food carotenoids: factors affecting carotenoid composition. Journal of Food Composition and Analysis 21, 445–463.

Roy, S.K., Chakrabarti, A.K., 2003. Vegetables of tropical climates. In: Commercial and Dietary Importance Encyclopedia of Food Sciences and Nutrition, pp. 5956–5961.

Toledo, A., Burlingame, B., 2006a. Biodiversity and nutrition: a common path toward global food security and sustainable development. Journal of Food Composition and Analysis 19, 477–483.

Toledo, A., Burlingame, B. (Eds.), 2006b. Biodiversity and nutrition: a common path. Journal of Food Composition and Analysis. 19, 6–7.

USDA U.S. Department of Agriculture, Agricultural Research Service, 2007. USDA National Nutrient Database for Standard Reference, Release 20. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl.

Van Jaarsveld, P.J., Faber, M., Tanumihardjo, S.A., Nestel, P., Lombard, C.J., Benadé, A.J.S., 2005. b-Carotene-rich orange-fleshed sweetpotato improves the vitamin A status of primary school children assessed with the modified-relative-dose–response test. American Journal of Clinical Nutrition 81, 1080–1087.

Van Jaarsveld, P.J., Marais, D.W., Harmse, E., Nestel, P., Rodriguez-Amaya, D.B., 2006. Retention of b-carotene in boiled, mashed orange-fleshed sweet potato. Journal of Food Composition and Analysis 19, 321–329.

Vuong, L.T., Franke, A.A., Custer, L.J., Murphy, S.P., 2006. *Momordica cochinchinensis* Spreng. (gac) fruit carotenoids reevaluated. Journal of Food Composition and Analysis 19, 664–668.

Wall, M.M., 2006. Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. Journal of Food Composition and Analysis 19, 434–445.

Warman, P.R., Havard, K.A., 1998. Yield, vitamin and mineral contents of organically and conventionally grown potatoes and sweet corn. Agriculture, Ecosystems & Environment 68, 207–216.

Wu, X., Sun, C., Yang, L., Zeng, G., Liu, Z., Li, Y., 2008. β-Carotene content in sweet potato varieties from China and the effect of preparation on β-carotene retention in the Yanshu No. 5. Innovative Food Science & Emerging Technologies 9, 581–586.