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Gerard Grubben, Wijnand Klaver, Rémi Nono-Womdim, Arij Everaarts, Lassina Fondio, Jan Arie Nugteren and Marina Corrado

INTRODUCTION

In tropical Africa, micronutrient deficiency, called 'hidden hunger', is a main cause of health problems, high mortality and low economic productivity (Biesalski, 2013). Nutritionists of WHO-FAO emphasize that a daily portion of various vegetables is essential for a well-balanced diet, in particular for children and pregnant women. In general, the intake of vegetables, the most affordable and accessible source of micronutrients, is low if compared to the recommended consumption[1]. Given this reality, it is expected that food security projects in tropical Africa should pay more attention to promoting vegetables for health. However, the emphasis has remained on research and development of energy rich staple crops (cereals, tubers, pulses) and cash crops. Compared to tropical Asia, the vegetable sector in Africa is lagging behind as a result of weak research, breeding, training and extension services, an insufficient seed distribution network and low purchasing power. Many policy makers ignore the nutritional and economic value of vegetables. Traditional cultural practices well suited to the prevailing subsistence agriculture cannot cope with the growing demand for vegetables for the urban markets. In countries like Ethiopia, Kenya, Tanzania and Senegal high-tech vegetable production for export to Europe and the Arabia Peninsula or for the small supermarket segment in the regional big cities has been supported with ample donor funding. However, exports represent only a very small part of the total vegetable production. The huge traditional domestic market, of crucial importance for the nutrition of the increasingly urbanized population, is almost devoid of public support. In this article, we want to sketch the scope of vegetable production for the domestic African markets and its importance for improvement of nutrition and health of the millions of consumers.

CAUSES AND CONSEQUENCES OF HIDDEN HUNGER

A recent global investigation into the incidence of hidden hunger by a team of experts (Muthayya et al., 2013) using growth stunting, anaemia due to iron deficiency and vitamin A deficiency as indices, found an alarmingly high level of hidden hunger in sub-Saharan Africa, with significant negative consequences for health and economic growth. Citation: *"As the term hidden hunger indicates, the signs of under nutrition and hunger are less overtly visible in those affected by it. Nevertheless, its negative and often lifelong consequences for health, productivity, and mental development are devastating. Young children and women of reproductive age living in low-income countries are the most vulnerable. …. Worldwide, the most widespread micronutrient deficiencies are of iron, zinc, vitamin A, iodine, and folate, but deficiencies of vitamin B12 and other B vitamins also commonly occur. In developing countries, multiple micronutrient deficiencies often occur together in the same population. … Countries in sub-Saharan Africa, the only developing region where the numbers of malnourished children have been rising in recent years, exhibited the highest rates of hidden hunger. … Of the 20 countries with the highest HH scores, 18 were in sub-Saharan Africa … Low quality diets, as well as frequent infections, are likely to be the key causal factors, further compounded by poor economic conditions and repressive political systems".*

[1] WHO-FAO recommend globally an average intake of fruit and vegetables at 400 g per person per day for balanced diets. Vegetables are richer in micronutrients than fruits, which have a high content of simple sugars (fructose, glucose). To prevent diabetes and obesity, an increasing problem also in African cities, a division of 60% vegetables (240 g/head/day) and 40% fruits (160 g/head/day) could be a global target. In this article, we propose for tropical Africa a doubling of the present intake of about 100 g to 200 g as a long-term realistic target.

Seed shop, Tanzania.

Tomato seedlings in field nursery, Tanzania.

Roadside nursery, Tanzania.

Peri-urban cultivation of jew's mallow, Ivory Coast.

STRATEGIES TO COMBAT HIDDEN HUNGER

Three different strategies can be used to combat hidden hunger: dietary diversification, supplementation with vitamins and minerals, and food fortification. These strategies should be considered complementary, all aimed at increasing micronutrient intake at individual and group levels. Although in general the consumption of whole foods has greater beneficial effects than taking dietary supplements containing isolated vitamins or minerals, nutrient supplements are urgently needed for groups at risk, mainly children and pregnant women. Food fortification with certain micronutrients has the entire population as its target group. Bio-fortification is a practice to increase the nutritional quality with a single micronutrient by plant breeding. It is applied to staple foods like golden rice, cassava and orange sweet potato for higher vitamin A. But the most obvious, natural and durable approach to combat hidden hunger is dietary diversification, mainly with vegetables, fruits and food of animal sources. A varied diet is the key to solving micronutrient deficiency problems. Several authors of the CABI-FAO study *"Combating micronutrient deficiencies: food-based approaches"* (Thompson and Amoroso, 2011) confirmed that it is possible to improve the health of vulnerable groups in a short period of time by increased vegetable consumption.

Harvest of African eggplant, Ivory Coast.

VEGETABLE PRODUCTION SYSTEMS

The 47 countries of tropical Africa, i.e. Western, Middle and Eastern Africa between the tropics, reaching from sub-Saharan Mauritania and Sudan to Botswana and Namibia, have a population of about 900 million, of which roughly 40% (360 million) live in cities. In official statistics, the definition of 'urban' is not always consistent, but in general it groups people living in densely populated areas (> 200 inhabitants per km^2) in towns with more than 15,000 people. Exact quantified data on the extent of production in areas and volumes, supply systems and the number of farmers and consumers are scarce and restricted to specific areas. Moreover, there is no clear distinction between the different production systems because they overlap each other. Therefore, we can only give a rough estimate of these factors.

Commercial Vegetable Production

Vegetables produced for the markets have become the most important source of vegetable consumption. Almost all urban people have to buy their fresh vegetables daily in street markets. The share of supermarkets is increasing but is still very minor (< 1% of the total supply) and restricted to high-income classes. In fact, there are more consumers than officially classified as urban. Also, the families living in villages or towns without land to grow their own vegetables and rural people with jobs beyond farming need to buy their daily requirement of vegetables from farmers or dealers on the local market. Our estimate is that at least 60% of the people of tropical Africa, 540 million consumers, depend on market vegetables. There is significant trading between African countries. Import or export trading with other continents, although for some countries of certain economic importance, will not be discussed here, because compared to the huge amount of vegetables required for the domestic African markets, these quantities are negligible.

Area, Yield and Production Data. Statistical data of vegetables per country can be found on FAOSTAT. These data provide basic information but need to be interpreted based on the following considerations. Some vegetable crops are harvested in one overall harvest, others by repeated pickings over a long period. Some fields are mono-cropped, others mixed-cropped or relay-cropped. Some fields have one crop per year, whereas in intensive peri-urban production several crops per year are grown on the same plot. Several vegetable crops are not recorded. For example, in the statistics of Ivory Coast, only okra, tomato and eggplant are recorded. For a rough estimate of the total area and production of vegetables in tropical Africa we suppose a net availability of 100 g/head/day. With 20% postharvest losses and 5% discarded peelings, this means gross 125 g/head/day or 46 kg/head/year. With an average yield of 12 t/ha per year (including multiple crops and multiple harvests), each hectare will feed about 260 urban consumers with their daily portion of vegetables. The total production needed for the about 540 million consumers depending on market vegetables is 25 million ton, on a cultivated area of 2.1 million hectares. With an average farm size of 0.5 ha, more than 4 million farmers are involved in vegetable production and many more people in packing, transport and trading of vegetables.

Peri-Urban Vegetable Production

Vegetable production in and near cities is called peri-urban production. It is practiced within a distance of some hours to the urban market, in marshy places, near rivers or anywhere where irrigation water is available[2] (Fondio et al., 2007). These producers grow vegetables with a short shelf life: leafy vegetables (amaranth, African nightshade, jew's mallow, baselle, sorrel, African kale, etc.), okra, tomato, eggplant, peppers but also exotic species like carrots, let-

[2] FAO has launched a global initiative on 'Growing Greener Cities' which provides policy guidance for the sustainable intensification of urban and peri-urban horticulture as a component of city development plans (WHO, 2004).

Applying manure on gboma eggplant, Benin.

Watering crops, Ivory Coast.

tuce, cucumber, Chinese cabbage, zucchini and French beans. If enough land is available and prices are high, also more bulk products with a longer shelf life like onion and cabbage are grown. Also papaya trees are often planted in these gardens. Production techniques are very labour-intensive and the size of these family farms is small, in the range of 1500-5000 m². These farmers use manure and town refuse as organic fertilizer and frequently also mineral fertilizer and synthetic pesticides. The seed of traditional vegetables is mostly farm-saved, whereas for exotic types like cabbage, carrots and lettuce they buy imported seed in specialized seed shops. More advanced technologies like hybrid seed, protected nurseries, plastic mulching, drip irrigation, integrated pest management and staking or trellis for plant support are still rarely used.

Organic Vegetable Production

There is a small (< 1% of total supply) market for organic vegetables, those produced without mineral fertilizer or synthetic pesticides. Usually there is no quality control or certification process. These organic products are more expensive than conventionally produced vegetables. Organic clients often embrace the belief that vegetables grown without mineral fertilizer have a higher nutritional value. Some people even believe that the 'normal' market vegetables are unhealthy or even toxic. The fact is that at the moment organic vegetables are targeted for the high-income classes only. The quantity of organic manure and compost available for vegetable growers is by far insufficient to provide the essential minerals (N, P, K, etc.) for the total vegetable area to produce a high yield.

Rural Commercial Production

Production of vegetables that can be kept for a few days after harvest and that can be easily transported, also called 'truck farming', is found at a distance from the urban markets, usually concentrated in places with fertile land, a favourable climate and with irrigation facilities. The most limiting factor is the transport costs. Access to reasonably good roads is needed for the trucks loaded with vegetables on the long trip, sometimes several days, from the farm to the wholesale market (Everaarts et al., 2011). Vegetables that can tolerate long distance transport are onions, shallots, carrots, potatoes, pumpkins, sweet corn and white cabbage. More perishable products often grown in commercial rural production are tomatoes, eggplant, okra, cauliflower, broccoli and watermelon. These production areas of thousands of hectares can be found in almost every country. In the highlands of Eastern Africa and in the semi-arid areas of West Africa, vegetables are transported daily by trucks to the big city markets in the lowlands. Onions, cabbage and even tomatoes are exported from Burkina Faso, Mali and Niger to Abidjan, Accra and Lagos. From the highlands of Tanzania and Kenya, vegetables are exported to Nairobi and Mombasa. Postharvest losses are high, up to 25%, due to bad road conditions and poor packing methods and storage facilities.

Family farms are mostly small scale, in the range of 0.4-1.5 hectares. They use hand labour or oxen for ploughing. Some are scarcely mechanized (tractors) and use modern technology like motorized pumps. Most cultivars (cultivated varieties) of western type vegetables are not well adapted to these tropical African conditions. If available, the farmers use limited amounts of mineral fertilizers. Plastic mulching, greenhouse nurseries and drip irrigation, very common in tropical Asia, are still rare in tropical Africa. The amount of manure or other organic fertilizer is mostly insufficient to get a reasonable yield and mineral fertilizer is expensive. Many pesticides are used, but farmers lack the skill for responsible and effective application. Compared to South East Asia the yield level is low, in the range of 6-10 t/ha per crop cycle. Much progress could be made by intensification and modernization.

Mixing pesticides, Tanzania.

Production for Personal Use in Fields and Home Gardens

Farmers traditionally grow vegetables as mixed cropping between their cereals, cowpeas or cash crops, utilizing the open spaces. Common field grown vegetables are okra, eggplant, pepper, tomato, pumpkin, egusi melon and many leafy vegetable species like roselle, amaranth and jew's mallow. These vegetables are grown from farm saved seed without much care and in a rather extensive way, without input of agrochemicals. The production takes place mostly in the wet season, sometimes with irrigation in the dry season. Also, many vegetables are grown in the compounds. Some people have well-kept home gardens, fenced to keep goats out and planted with vegetables, fruits and other useful plants in an intensive way, irrigated when needed, the soil kept fertile with household waste and farm yard manure. Mostly, however, it is a rather haphazard assortment of useful plants, grown without much care or input. Typical vegetables for home gardens are climbing plants like Ceylon spinach (*Basella alba*), lablab (*Dolichos lablab*), lima beans (*Phaseolus lunatus*), fluted pumpkin (*Telfairia occidentalis*), pumpkins and drought resistant perennial vegetables like bitter leaf (*Vernonia amygdalina*) and drumstick tree (*Moringa oleifera*). Home gardens are important as sources of fruits, mainly papaya, banana, citrus and mango. Cassava and sweet potato are also grown in the compounds, as dual-purpose crops for their tubers and as leafy vegetables. Most people in rural areas get a large part of their daily vegetable supply from this type of subsistence farming, and surpluses are often sold in local markets. Also, in peri-urban areas and even in

Spraying potatoes, Tanzania.

Washing and preparing carrots for transport, Tanzania.

the cities, some families grow vegetables on a small scale in their compounds. A rough guess is that about 30% of all vegetable production in tropical Africa consists of cultivated vegetables in the field, with home gardens supplying mainly for personal consumption.

Collection of Indigenous Wild Vegetables

Rural people traditionally pick and gather edible plants, mostly leafy vegetables from wild vegetation to be used as potherbs. This makes up part of their subsistence food system. These people in remote areas outside the commercial circuit still partly depend on food gathering. An example of the wild plants gathered by these people is wild jute (*Corchorus tridens*), a common weed much liked for its mucilaginous properties and popular in arid areas for the preparation of dried leaf powder, an important ingredient in sauces during the dry season. Some other popular weedy vegetables are wild amaranths (*Amaranthus* spp.), spider plants (*Cleome gynandra*), false sesame (*Ceratotheca sesamoides*), slenderleaf (*Crotalaria brevidens*), fireweed (*Crassocephalum crepidioides*) and water leaf (*Talinum triangulare*). These species are sometimes cultivated. They are in a stage of proto-domestication and are often called 'underutilized vegetables' or 'orphan vegetables'. The PROTA vegetable handbook describes about 200 of these wild vegetable species (Grubben and Denton, 2004). Many of these species are not really liked and are only gathered as emergency or famine food when more palatable vegetables are unavailable. While weeding their cereal or cotton fields, farmers practice selective weeding, sparing the edible weeds. Also, many spontaneous shrubs and trees are left growing as they are sources of vegetable products. The most important is the baobab tree (*Adansonia digitata*), the leaves being used fresh or dried and powdered. Many products from this collection system can be found at local markets but their supply to urban markets is fast decreasing. At present, probably only 10% or less of the total vegetable consumption in tropical Africa is derived from the gathering of wild edible plants. This decrease is a consequence of many causes including urbanization, the decline of spontaneous vegetation by overgrazing, modernization of agricultural methodology and diversification of family income beyond farming. The share of these gathered vegetables in the total vegetable supply is expected to drop further.

Underutilized or Orphan Vegetables. The fact that the volume of market vegetables on the whole should be increased does not necessarily mean that the best policy to increase vegetable consumption in Africa is to promote the neglected, underutilized species, the 'orphan vegetables'. For obvious commercial reasons, private sector companies are devoting the bulk of their resources to the breeding of a limited number of common species like tomato, peppers, onion, cabbage, okra and eggplant. However, in view of the rather limited assortment of these species, and in order to broaden the diversity, a number of the underutilized species with a sufficient yield potential should be upgraded by research and market development.

Indigenous, Traditional and Exotic. In the literature, the terms 'indigenous' and 'traditional' species are often erroneously used. **Indigenous species** have their origin in tropical Africa. Okra, African eggplant, watermelon, baobab, spider plant, roselle, jew's mallow, egusi melon, Lagos spinach, fluted pumpkin, bitter leaf, gboma eggplant, cowpea, and many wild or semi-domesticated species are indigenous. **Traditional species** are vegetables that are commonly used by the local population since many generations, but they are not necessarily of indigenous origin. Thus, all indigenous species may be called traditional, but also early introductions from abroad that are now commonly used, like Capsicum peppers, tomatoes, onions, pumpkins, amaranth, leaf cabbage (sukuma wiki), Ceylon spinach, cassava leaves and sweet potato leaves, are traditional vegetables. Indigenous and traditional are the opposite of **exotic**, which refers to species from other continents introduced in recent colonial times. They are often called Western or European vegetables, even when the origin is Asia or America. Examples of these exotic species penetrating African food habits are carrots, cucumber, potato, French beans, lettuce, garlic, zucchini, cabbage, cauliflower, Chinese cabbage, sweet corn and eggplant.

Plant Breeding and Vegetable Seed

In Africa most farmers still use farm-saved seed or they buy cheap locally produced or imported seed of OP (open pollinated) cultivars, often of inferior quality. In tropical Asia, where the yield level is much higher, up to 30 t/ha/year, the great majority of farmers use high quality seed. Almost all cultivars of solanaceous species (tomato, eggplant, peppers) and cucurbits and most okra, sweet corn and cole crops in Asia are hybrids with superior yield and high resistance to pests and diseases (Batt and Jayamangkala, 2009). Only few of the large international seed companies are really specialized in tropical vegetables and have an increasing assortment of OP and hybrid cultivars adapted to tropical African conditions.

VEGETABLES IN THE DAILY MENU

Vegetables are an essential part of the daily meals. They serve as relish for the main dish and make the starchy staple foods more palatable. Vegetables are prepared as a stew dish, apart or as ingredient of soups and sauces, with meat or fish, oil and spices. Maize and cassava are the leading staple food crops, next to sorghum, rice, millet, yam, sweet potato, plantain and cocoyam. Vegetables are often served in combination with a pulse dish, mainly groundnut, cowpea and common bean. Mucilaginous vegetables like okra, roselle, Ceylon spinach and jew's mallow are needed for easy consumption of the starchy staple foods. The most important market vegetables in quantity and value are tomatoes, onions and hot peppers, because they are used daily. Okra, African eggplant, cabbage, eggplant, pumpkins and carrots are important products. Leafy vegetables as a whole are the most important in quantity and are consumed almost daily. Important leafy vegetables are amaranth, celosia (Lagos spinach), jew's mallow, roselle, gboma eggplant, African nightshade, spiderplant, bitter leaf, and the leaves of pumpkin, cowpea, cassava, sweet potato and cocoyam. Salad vegetables like cucumber and lettuce, formerly unknown in African diets, are becoming increasingly important for urban consumers. As a conse-

Peri-urban hot pepper harvesting, Ghana.

Preparing tomatoes for transport, Tanzania.

quence of historical background and different agro-ecological conditions, differences between countries and regions are large. For instance, African kale (sukuma wiki) is the number one vegetable in Kenya, but is unknown in West Africa. Lagos spinach is very popular in the coastal area of Nigeria and Benin, but almost unknown in most African countries.

Common Vegetable Dishes of the Sudanian and Guinean Zones of West Africa

While exact data on area, yield and production per species are scarce, nutritional surveys can provide some clarity. For example, the report entitled *"Traditional recipes of millet-, sorghum- and maize-based dishes and related sauces frequently consumed by young children in Burkina Faso and Benin"* (Greffeuille and Mouquet-Rivier, 2010) describes popular sauces and vegetable dishes observed in 132 regular low budget households. The dishes described for Burkina Faso can be seen as representative of the urban population in the semi-arid Sudanian zone of West Africa, while those described for Cotonou are representative of the humid southern coastal zone, the Guinean zone. The size of households was not recorded. Presuming that these dishes, along with the staple food, are consumed by an average family of five persons (3 children and 2 adults) and that no other vegetables are used, the daily vegetable consumption in Ouagadougou is about 140 g per head, which is 70% of the target of 200 g. The most important ingredients are leafy vegetables 64 g, onion 26 g, okra 23 g, tomato (fresh, dried, or as purée) 18 g and hot pepper 2 g. The popular cultivated leafy vegetables are roselle, jew's mallow, gboma eggplant, African eggplant leaves, amaranth and leaves of cowpea, cassava and baobab. In the dry season, hot pepper, okra and several leafy vegetables are much used as a dried product. In Cotonou, the daily intake is 126 g or 63% of the recommended portion. The consumption of leafy vegetables is 43 g, tomato 45 g, onion 14 g, okra 7 g, peppers 6 g and egusi (cucurbit seeds) 4 g. Néré or soumbala (fermented seeds of *Parkia biglobosa*) is a popular condiment, but in the city it is often replaced by stock cubes. Table 1 lists the species cited in these menus.

CONTRIBUTION OF VEGETABLES TO THE DAILY REQUIREMENTS

It is not easy to get an accurate idea of the quantity of micronutrients that vegetables contribute to the nutritional value of the daily meal. Food composition tables are usually based on the nutrient content per 100 g of fresh product. In contrast to cereals, pulses, roots and tubers, the water content of vegetables is high and highly variable. The high water content is illustrated in Figure 1. Besides, during preparation, cereals and pulses absorb much cooking water, but the quantities also vary. Therefore dry matter (DM) is a more appropriate denominator when comparing the nutritive value of vegetables and other foods.

The macronutrient content of vegetables is quite different from staple foods. A comparison between the macronutrient and fibre contents of some vegetables, staple foods and fruits is presented in Figure 2. It shows that most vegetables have a remarkably high protein content. The leafy vegetables are even as rich in protein as legumes. Conversely, vegetables contain less carbohydrates than staple foods and fruits. Vegetables are rich in structural tissue (protein

Table 1. Common vegetable species in Sudanian Zone (1) and Guinean Zone (2).

Scientific name	English	French	Vernacular names
Leafy vegetables			
Adansonia digitata 1	Baobab	Baobab	Toega
Amaranthus cruentus 1,2	Amaranth, spinach	Amarante	Brombrou, fotètè
Celosia argentea 2	Lagos spinach, celosia	Celosia	Soman, avounvo
Corchorus olitorius 1,2	Jew's mallow	Corète potagère	Krinkrin, bulvaka
Hibiscus sabdariffa 1	Roselle, sorrel	Oseille de Guinée, roselle	Dah, bito
Hibiscus cannabinus 1	Kenaf	Kénaf	Dah
Manihot esculenta 1,2	Cassava	Manioc	Fingninman
Senna obtusifolia 1	Sicklepod	Séné, casse fétide	Kiri-kiri
Solanum americanum 1,2	Glossy nightshade	Morelle africaine	Fouet
Solanum scabrum 1,2	African nightshade	Morelle africaine	Fouet
Solanum macrocarpon 2	Gboma eggplant	Gboma eggplant	Gboma
Vernonia amygdalina 2	Bitter leaf	Vernonie	Amanvivé
Vigna unguiculata 1,2	Cowpea	Niebé	Bengedo
Vitex doniana 2	Black plum	Prune noir	Fonman
Non-leafy vegetables			
Abelmoschus esculentus 1,2	Okra	Gombo	Maana
Abelmoschus caillei 2	West African okra	Gombo ouest-africain	Maana
Allium cepa 1,2	Onion, shallot	Oignon, échalote	
Allium sativum 1,2	Garlic	Ail	
Capsicum annuum 1,2	Chilli, hot pepper	Piment	Kiparé
Capsicum chinense 2	(Aromatic) hot pepper	Piment chinois	Kiparé
Capsicum frutescens 1,2	Bird pepper	Piment oiseau	Kiparé
Citrullus lanatus 1,2	Egusi melon	Pastèque égoussi	Egusi, goussi
Cucumeropsis mannii 2	Egusi	Égoussi	Goussi
Lagenaria siceraria 1,2	Bottle gourd, egusi	Seed calebasse	Egusi, goussi
Lycopersicon esculentum 1,2	Tomato	Tomate	
Parkia biglobosa 1,2	Néré	Néré	Soumbala, afitin
Solanum aethiopicum 1	African eggplant, gilo	Aubergine africaine	Djakattou, kumba
Solanum melongena 1,2	Eggplant	Aubergine	

Figure 1. Components of selected foods (in kg) that provide 100 g of dry matter.

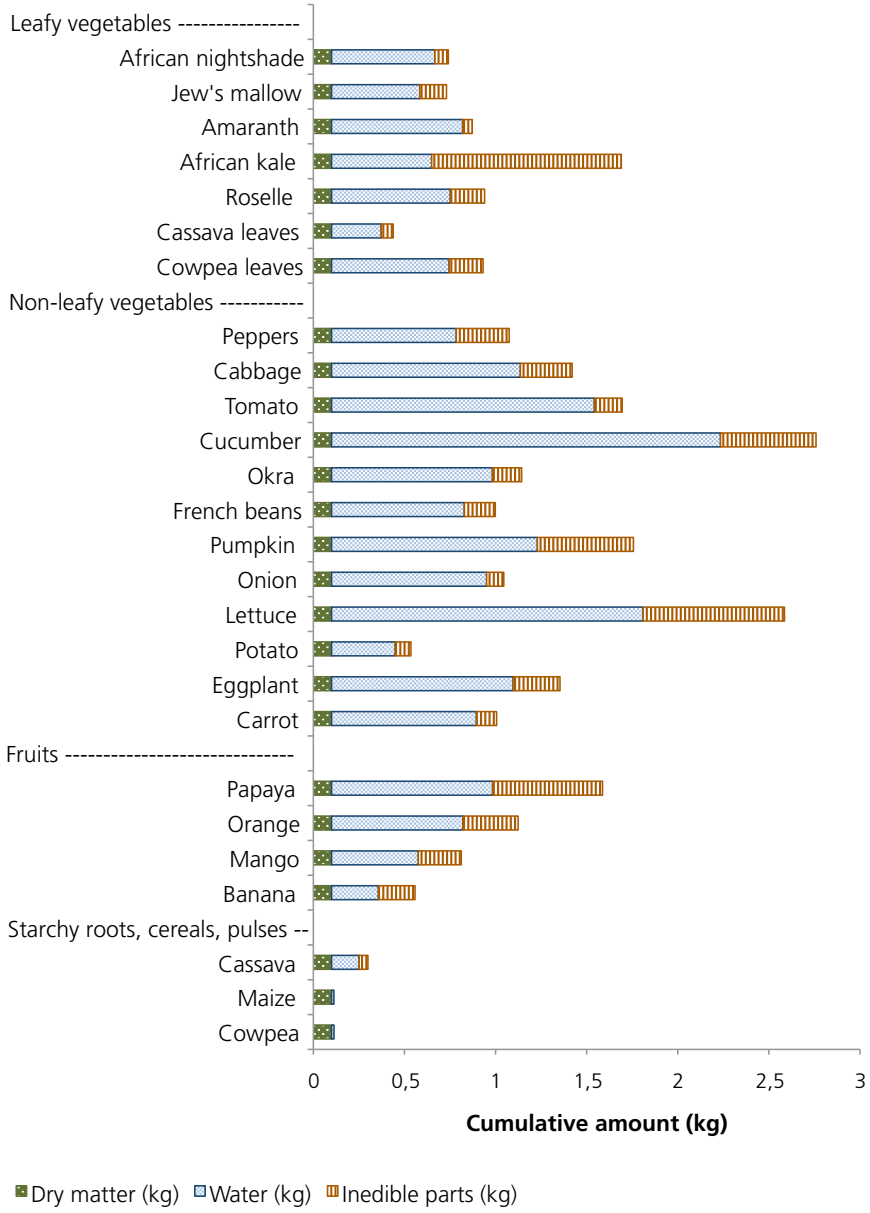


Table 2. Recommended nutrient intake (RNI) for a 7-9-year-old child and nutrient supply (after cooking) from a portion corresponding to 22 g dry matter of amaranth, tomato or okra.

Nutrient	RNI per day	Nutrient contribution of vegetables			
		Retention upon cooking	Amaranth 180 g fresh = 22 g DM	Tomato 317 g fresh = 22 g DM	Okra 194 g fresh = 22 g DM
Energy (kcal)	1069	1.00	70	75	84
Dietary protein (quality score 0.75) (g)	30.5	1.00	6.8	3.4	3.7
Calcium (mg)	700	0.95	651	42	172
Dietary iron (10% bioavailable) (mg)	8.9	0.75	8.4	1.5	1.3
Zinc (low bioavailability) (mg)	11.2	0.90	1.2	2.1	1.2
β-carotene eq. (provit. A) (µg)	6000	0.90	4690	1905	609
Thiamin (mg)	0.7	0.65	0.05	0.13	0.06
Riboflavin (mg)	0.9	0.65	0.39	0.09	0.11
Folate (µg)	300	0.50	71	36	95
Vitamin C (mg)	35	0.40	33	40	24

and fibre) and ash, which goes together with a high content of micronutrients (minerals, vitamins and other bioactive compounds). This is why vegetables are an important part of the diet in order to avoid micronutrient deficiencies such as vitamin A, zinc and iron. In addition to minerals and vitamins, the high dietary fibre content of vegetables is important for the healthy functioning of the gastrointestinal tract and the prevention of dietary induced chronic diseases, such as cardio-vascular diseases, various forms of cancer, diabetes and obesity.

Energy and nutrient requirements increase with age. From adolescence on, sex makes an important difference. Women have more body fat and less lean body mass than men and therefore have lower nutrient requirements per kg of body weight under normal circumstances, but the reproductive functions of women imply increased nutritional needs. In Table 2, we have taken a 7-9-year-old child as reference for the Recommended Nutrient Intake (RNI) (FAO/WHO, 1998; FAO/WHO/UNU, 2001, 2007). As 100 g dry matter corresponds to on average 905 g fresh vegetables (excluding cucumber), the target of 200 g fresh vegetables per day translates into 22 g dry matter. For linking the scales of nutritional requirements with Food Composition Tables, losses by cooking as well as the bio-availability of the nutrient in question must be taken into consideration. In this table, the contribution of micronutrients from a daily portion of 180 g of fresh amaranth, 317 g fresh tomato or 194 g fresh okra (all providing a target amount of 22 g dry matter) are presented as examples of the impact of vegetables in reaching a balanced diet. The table illustrates that more weight would be needed of vegetables with a higher than average water content, and that all three vegetable species contribute considerably to the daily micronutrient requirement. Amaranth, representing dark green leafy vegetables, provides a non-negligible quantity of protein. In this quantity of 180 g fresh, a portion that can easily be consumed with two meals, it fulfills in itself more than 90% of the daily requirement of calcium, iron and vitamin C, as well as almost 80% of the provitamin A. The remainder may come from other food groups in the diet. If not, a small increase in amount per day will suffice. No food item can be complete on its own and much variation is an indispensable requirement for a balanced diet. It is also clear that even an average daily portion of 200 g of fresh vegetables is a minimum target. Especially when animal products (meat, fish, dairy products) are lacking, it is wise to further increase the vegetable portion to, for instance, 300 g.

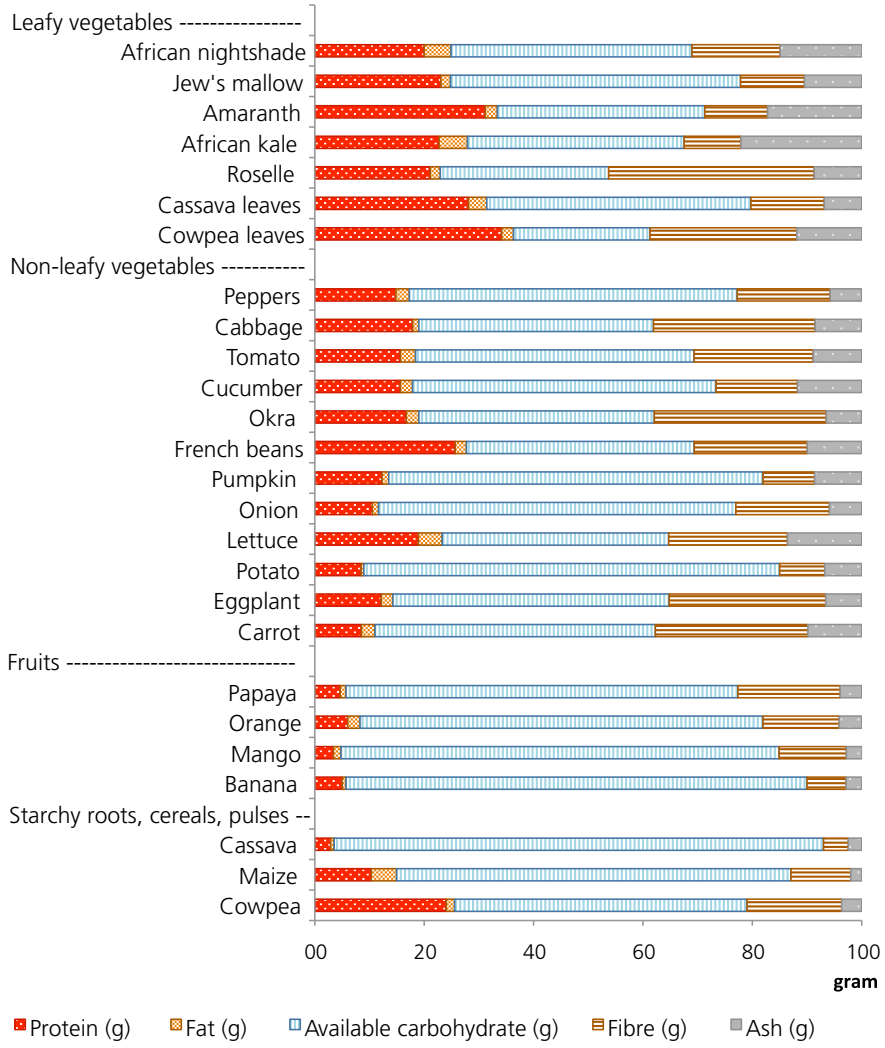
Table 3 is a Food Composition Table showing a number of common vegetables on a dry matter basis.

For comparison, some fruits and staple foods are also included. For more detailed information, the interested reader may consult the nutrition literature mentioned in the references.

Lagos spinach in home garden, Benin.

Planting amaranth, Benin.

Figure 2. Macronutrient composition (proximate analysis) of selected foods per 100 g dry matter.



DISCUSSION AND RECOMMENDATIONS

Combating hidden hunger needs a complex approach, requiring interventions in different areas linked to food production, marketing, processing and consumption. Vegetables are excellent sources of micronutrients and are affordable for consumers if supply to the market is sufficient. Besides their nutritional qualities, vegetables offer excellent opportunities for productivity increase for farmers, and therefore for income improvement. The vegetable sector offers much employment and ample business opportunities and is therefore a unique sector for economic development at local level, providing income security for workers in rural areas.

To satisfy the need of all citizens for a well-balanced diet, a target of at least 200 g of fresh vegetables per day, or 73 kg per head per year, must be pursued, which means that current vegetable intake should be doubled. Taking into account a loss of 25% from the field to the table, ideally 91 kg gross weight of various vegetables per consumer should yearly become available at the farmgate. For the 540 million consumers depending on urban vegetable markets at present, farmers would need to produce 50 million tons per year. With a wide introduction of improved cultivars bred for African conditions, combined with better production technology, transport and marketing facilities, the current yield level could be doubled, to the benefit of the farmers, consumers and other stakeholders in the vegetable chain. The best solution would be to intensify production by using improved cultivars and cultivation technology. With an increased yield from the present 12 t to 20 t/ha per year, at least a realistic objective in the medium term, this quantity could be produced without any increase in the cultivated area or even on a smaller land area, while the costs for labour and inputs (pesticides, fertilizer, irrigation) per kg of harvested product would be reduced.

Extensive cultivar testing and conventional plant breeding, gradually including some modern technologies, must be undertaken by lead research institutions and national and international seed companies who have the technical knowhow on breeding, seed production, seed technology and distribution. In tropical Asia, seed companies released superior hybrids and OP (open pollinated) cultivars of many species which, combined with improved cultivation practices, caused a spectacular yield increase, as was clearly shown in an international ISHS symposium in Thailand (Batt and Jayamangkala, 2009). This Asian green vegetable revolution has not yet taken place in tropical Africa. Research on cultivation practices of traditional vegetable species should be enhanced (Nono-Womdim et al., 2012). The vegetable seed industry is very complex and in many ways different from that of cereals and pulses. Governmental institutions, sometimes successful in cereal breeding and seed production, are usually not successful in high quality vegetable breeding and seed production. Breeding of high yielding cultivars with multiple disease resistance and suitable for domestic markets should be part of the commitment to combat hidden hunger in Africa. Besides this urgent need to raise the commercial supply of vegetables, production in fields and home gardens for owner consumption should also be stimulated.

To date, the economic potential of the African vegetable sector is not living up to its potential. Public institutions, universities and international research institutes should devote more effort to

Preparing vegetables in the kitchen, Ivory Coast.

Bulk transport of cabbage, Tanzania.

Table 3. Restricted food composition table of common African vegetables based on 100 g dry matter.

Content per 100 g DM	Water in fresh food (g per 100 g DM)	Energy (kcal)	Macronutrients					Minerals			Vitamins				
			Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)	Ash (g)	Ca (mg)	Fe (mg)	Zn (mg)	β-carotene equivalent (µg)	Thiamin (mg)	Riboflavin (mg)	Folate (µg)	Vit. C (mg)
Leafy vegetables (raw)															
Amaranth	720	320	31.1	2.2	37.9	11.5	17.2	3115	50.8	5.9	23689	0.3	2.70	648	369
Jew's mallow	485	345	23.1	1.8	53.0	11.7	10.5	2105	24.6	2.6	18299	0.9	3.10	690	468
African kale	549	317	22.7	5.2	39.6	10.4	22.1	857	8.4	3.6	3247	0.0	0.84	916	714
Afr. nightshade	567	332	20.0	4.9	44.1	16.1	14.9	2067	85.0	23.0	n.a.	n.a.	n.a.	n.a.	n.a.
Roselle	652	301	21.1	1.8	30.8	37.6	8.7	1596	30.8	6.8	19398	1.3	3.38	880	248
Cassava leaves	273	361	28.1	3.4	48.3	13.4	6.8	1029	20.5	2.6	12779	0.9	1.70	440	145
Cowpea leaves	645	313	34.2	2.2	25.0	26.8	11.9	1978	37.9	3.7	13415	1.5	2.76	961	425
Non-leafy vegetables (raw)															
Carrot	795	313	8.5	2.5	51.3	27.9	9.8	313	6.3	2.3	76624	0.5	0.43	281	63
Cucumber	2135	335	15.6	2.2	55.5	14.9	11.7	291	10.1	3.8	782	0.4	0.22	134	313
Eggplant	996	329	12.1	2.1	50.5	28.6	6.6	141	10.0	1.6	329	0.5	0.49	289	69
French beans	729	331	25.7	2.1	41.6	20.7	9.9	391	9.0	2.3	2372	0.8	0.83	511	145
Lettuce	1710	326	19.0	4.3	41.4	21.7	13.6	489	14.1	5.3	20271	1.1	2.71	1611	96
Okra	883	324	16.7	2.3	43.0	31.5	6.5	822	8.0	5.9	3077	0.4	0.79	865	273
Onion	851	352	10.5	1.1	65.3	17.1	5.9	239	2.9	2.5	10	0.5	0.39	152	98
Peppers	685	353	14.8	2.5	60.0	17.0	5.8	126	8.7	2.2	5019	0.6	0.69	180	1515
Potato	350	360	8.5	0.5	76.0	8.3	6.7	48	3.9	1.6	61	0.4	0.53	79	78
Pumpkin	1130	357	12.3	1.2	68.4	9.4	8.6	238	14.8	3.9	14754	0.6	0.25	98	98
Tomato	1442	339	15.7	2.8	50.9	21.8	8.9	200	9.3	10.8	9619	0.9	0.63	328	457
Cabbage	1036	318	17.9	1.1	42.9	29.5	8.5	466	6.3	2.3	1131	0.5	0.42	550	614
Cereals, starchy roots, pulses															
Maize, white	13	400	8.6	3.3	81.0	6.2	0.9	7	1.4	1.7	0	0.4	0.06	33	0
Cassava	152	385	2.9	0.7	89.5	4.5	2.4	108	1.8	0.9	38	0.1	0.13	60	75
Cowpea	13	358	24.0	1.5	53.5	17.3	3.7	93	8.3	5.2	37	0.8	0.17	473	1
Fruits															
Orange	720	369	6.0	2.3	73.7	13.9	4.1	253	1.3	0.8	741	0.3	0.27	273	384
Banana	257	379	5.0	0.7	84.3	7.1	2.9	21	1.1	0.7	5107	0.1	0.14	61	48
Papaya	884	354	4.6	1.1	71.7	18.7	3.9	201	6.7	1.2	9801	0.3	0.31	246	571
Mango	476	369	3.4	1.4	80.0	12.3	2.9	100	4.0	0.6	11643	0.2	0.27	146	209

n.a. = data not available. Sources: West African food composition table (Stadlmayr et al., 2012); African kale: Leung et al., 1968; African nightshade: Charrondière et al., 2012.

collaborating with the private sector to create partnerships for the enhancement of on-farm research, on-farm cultivar testing, demonstration of good agricultural practices, access to sources of resistance genes and in education and training[3]. It is understandable that breeding and seed companies in Africa will first focus their breeding efforts on the most remunerative species, such as tomato, onions, peppers, eggplants, okra, watermelon, cabbage and carrots. Gradually they will extend their range to include species that are currently of lesser economic importance, but which have increasing business potential.

The present vegetable consumption in tropical Africa is clearly too low for balanced healthy nutrition. It is highly recommended that the African governments adopt programs for research and extension concerning traditional diets, food habits, changing eating behaviour and diet related health problems. To raise the consumption of vegetables, nutritional education, training and extension are needed for workers in health care, teachers, and medical personnel and for the public at large. School gardens are an excellent tool to educate the

[3] An example is the recently started Public-Private project SEVIA (Seeds of Expertise for the Vegetable Industry of Africa) in Tanzania, with activities in the East African region. The purpose is to contribute to the food security strategy and vegetable industry development by providing adapted cultivars to the farmers and by setting up an African Institute for Vegetable Technology (IVT).

Roadside selling of vegetables, Ghana.

Vegetable market, Benin.

youth and their parents. The agronomy sector and the health care sector should join their efforts to eradicate hidden hunger.

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