

EFFORTS TO PROMOTE AMARANTH PRODUCTION AND CONSUMPTION IN UGANDA TO FIGHT MALNUTRITION

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ABSTRACT

Malnutrition is widespread in sub-Saharan Africa. Easy-to-grow nutrient rich foods can help to improve nutrition and food security among communities that heavily depend on subsistence agriculture. In this chapter, efforts to promote grain amaranth in Uganda are described. Grain amaranth was introduced in Kamuli District, Eastern Uganda by VEDCO, a non-governmental organization, in 2005. Makerere University provided technical support to this initiative with Makerere University scientists undertaking studies to determine the nutrition profile of the grain; developing protocols for production of amaranth-based value-added food products; and evaluating the effect of dietary incorporation of grain amaranth on the nutrition status of children. Results show that amaranth grains are high in protein and the proteins are of high quality. The grains are also rich in unsaturated fatty acids, especially linoleic acid, and contain substantial levels of essential micronutrients. Grain amaranth was also found to make acceptable soups, fried and baked products. Feeding trials so far show that grain amaranth leads to improved growth among children. Results from these studies show that grain amaranth has the potential to contribute to improvement of the nutritional status of communities with high levels of malnutrition. The results have been used by extension staff to design evidence-based promotional messages for grain amaranth production and consumption.

INTRODUCTION

Malnutrition is widespread in Uganda and other developing countries. It is a major direct and indirect cause of infant and childhood mortality and morbidity. Besides children, other vulnerable individuals such as people living with HIV and AIDS (PLWHA) have high nutrient requirements. The poor are unable to access adequate amounts of nutrient-rich foods to meet dietary requirements and this is the major reason for the high prevalence of malnutrition. Data from 1995 to date show a prevalence of stunting among children aged <5 years in Uganda ranging between 37 – 39%. Statistics from other countries in sub-Saharan Africa and South East Asia are not much better. There is therefore a need to identify nutrient-rich foods that can be produced inexpensively to meet the nutrient requirements for these vulnerable groups.

Grain amaranth has the potential to contribute to addressing the nutritional needs of vulnerable people because of its high protein content, superior protein quality, high content of essential fatty acids and micronutrients.



Figure 1: Amaranth plant (head loaded with seeds)

Amaranths, which comprise the genus *Amaranth*, are widely distributed, short-lived herbs, occurring in temperate and tropical regions. There are about 60 *Amaranth* species, several of which are cultivated as leaf vegetables, grains or ornamental plants, while others are weeds (Kauffman and Weber, 1990). The main species grown as vegetables are *A. tricolor*, *A. dubius*, *A. lividus*, *A. creuntus*, *A. palmeri* and *A. hybridus* while *A. hypochondriacus*, *A. cruentus* and *A. caudatus* are the main grain species (Teutonico and Knorr, 1985). Amaranth produces a large amount of biomass in a short period of time (Kauffman and Weber, 1990) and therefore has the potential to contribute to a substantial increase in world food production. Grain yield of up to 5,000 kg/ha has been reported (Stallknecht and Schulz-Schaeffer, 1993).



Figure 2: Dry raw amaranth seeds

Amaranth is one of the few plants whose leaves are eaten as a vegetable while the seeds (Figure 2) are used in the same way as cereals; there is no distinct separation between the vegetable and grain types since the leaves of young plants grown for grain can be eaten as both human and animal food. When the leaves are harvested in moderation, the grain yield is unaltered. Vegetable amaranth species are utilized for food in different parts of the world. Grain amaranth can be used as seeds or flour to make products such as cookies, cakes, pancakes, bread muffins, crackers, pasta and other bakery products (Teutonico and Knorr, 1985). Kauffman and Weber (1990) provided a description of the variety of products made from amaranth in different parts of the world. These include soups and stews from whole grain; *alegria*, a confection made from popped amaranth in Mexico; *atolea*, a fermented Mexican drink made from roasted amaranth flour; *chichi*, which is a form of beer made from amaranth in Peru; *sattoo*, a gruel consumed in Nepal, and *chapatti* made in different parts of Asia.

NUTRITION AND HEALTH BENEFITS OF GRAIN AMARANTH CONSUMPTION

Consumption of grain amaranth is reported to have nutritional and health benefits, ranging from a general improvement in well-being to prevention and improvement of specific ailments and symptoms including recovery of severely malnourished children and an increase in the body mass index of people formerly wasted by HIV/AIDS (SRLP, 2005; Tagwira *et al.*, 2006). Tagwira *et al.*, (2006) documented perceived benefits of consuming grain amaranth among communities in Zimbabwe. The communities claimed that eating grain amaranth made them feel healthier and they noticed improvements in the health of their children. Specific health improvements noted included improvement in appetite, fast healing of mouth sores and herpes zoster, and weight gain for PLWHAs. Amaranth consumption was also associated with higher milk production among breast feeding mothers.

The improvements in general well-being and health reported by people who included grain amaranth in their diets are generally explainable by its high nutritional value. Some specific nutritional and health benefits of amaranth consumption have been elucidated. Amaranth oil has been shown, in animal studies, to lower total serum triglycerides and levels of low density lipoproteins (LDL) (Esculedo *et al.*, 2006). Similar effects have been reported in humans (Martirosyan *et al.*, 2007). High levels of serum LDL are associated with coronary heart disease. The serum LDL lowering effect of amaranth has been attributed to the tocotrienols (unsaturated forms of vitamin E) and squalene in amaranth oil. These compounds affect cholesterol biosynthesis in humans (Martirosyan *et al.*, 2007). They are also believed to have anti-tumor and antioxidative activity (Kim *et al.*, 2006a), pointing to potential anti-cancer effects.

Supplementation of patients with coronary heart disease with amaranth oil has been shown to contribute to a decrease or disappearance of headaches, weakness, increased fatigability, shortness of breath during a physical activity, edema of the legs towards the evening hours and feeling of intermission of heart function in most patients (Martirosyan *et al.*, 2007). In addition, decrease in body weight has also been reported. Consumption of grain amaranth has also been shown to have potential benefits to diabetics. Studies suggest that supplementation of diets with amaranth grain and amaranth oil improves glucose and lipid metabolism in diabetic rats (Kim *et al.*, 2006b). The fasting serum glucose levels and the glucose tolerance of the diabetic rats were both improved.

INTRODUCTION OF GRAIN AMARANTH IN UGANDA

Grain amaranth was introduced to Kamuli district, Uganda in 2005 by local NGO Volunteer Efforts for Development Concerns (VEDCO) under a program called Sustainable Rural Livelihoods (SRL). VEDCO has partnered with Makerere University to undertake studies on the nutritional value of the common varieties of grain amaranth grown to inform the promotional activities. Studies have also been conducted on the processing and preparation of grain amaranth.

Under the SRL program, extension workers were trained on aspects of grain amaranth production, nutritional value, preparation and processing methods. The trained extension workers were then charged with introducing grain amaranth to communities in Kamuli district. The aim was to promote grain amaranth for household food and nutrition security among the small and medium holder farmers and groups of disadvantaged people.

Grain amaranth demonstration and multiplication gardens were established to provide a source of seeds for farmers interested in producing and consuming the crop. Farmers were trained in seed production, selection and management and given seeds to establish seed multiplication plots on their farms. Two varieties of grain are now widely grown and these are identified as golden and white. The yield on farm gardens is around 3 tonnes per hectare but farmers maintain rather small gardens (average is less than a quarter of a hectare).

Currently, there seems to be no clear market for grain amaranth. Efforts towards market development are therefore required. Product development and value addition could be used to create markets for the crop.

Because the current demand for amaranth is not large, production is low. Community members are producing what they can consume themselves and small quantities for selling locally. In addition a few buyers come from elsewhere e.g., Makerere University Food Science staff, VEDCO staff, relatives and friends. There is need for massive demand creation.

NUTRITION COMPOSITION OF GRAIN AMARANTH

Analysis of grain amaranth obtained from farmers' fields showed that the grains were rich in proteins, lipids, energy and fiber (Table 1).

Table 1: Proximate composition of grain amaranth varieties commonly grown in Kamuli, Uganda

Nutrient	%	
	White amaranth	Golden amaranth
Protein	12.37	13.04
Carbohydrate	63	63.4
Lipid	6.89	7.29
Fiber	6.33	7.01
Ash	2.85	3.60

Amaranth grains are also known to contain substantial amounts of vitamins and minerals (Table 2). Amaranth grains contain twice the level of calcium found in milk, five times the level of iron in wheat, and higher sodium, potassium and vitamins A, E, C and folic acid than cereal grains (Becker *et al.*, 1981).

Table 2: Amaranth content of selected vitamins and minerals

Nutrient	Content (mg/g)
Iron	17.4
Zinc	3.7
Sodium	31
Potassium	290
Calcium	175
Vitamin C	4.5
Niacin	1.45
Riboflavin	0.23
Thiamine	0.1

Source: www.eap.mcgill.ca/CPAT_1.htm: Accessed November 2008.

Grain amaranth has higher levels of protein than most grains and its protein is of higher quality than that of most cereals and pulses. The varieties grown in Uganda have been found to have protein content of 12-13%, which is higher than that of most cereal grains and other common staples. Grain amaranth proteins contain substantial amounts of the essential amino acids that tend to be marginal in common cereals and pulses (Table 3). The level of lysine in both varieties grown in Uganda was found to be above the FAO/WHO reference and more than double the level reported for maize. Methionine levels in the amaranth grains, though slightly lower than FAO/WHO recommended level, is about 3

times the levels in beans. However, amaranth has lower levels of threonine and phenylalanine than the FAO/WHO reference protein and marginal levels of leucine and valine. It should be noted however, that the essential amino acids that are low in amaranth are quite abundant in most diets.

Table 3: Amino acid composition of grain amaranth varieties commonly grown in Uganda in comparison to that of maize and beans

Amino Acid	Content (g/100 g protein)				
	White amaranth	Golden amaranth	Maize	Beans	FAO/WHO Reference
ASPARTIC ACID	7.929	7.492	7.48	10.61	
GLUTAMIC ACID	19.248	19.720	18.37	13.29	
SERINE	6.462	6.090	4.51	4.85	
GLYCINE	8.983	8.700	3.85	3.3	
HISTIDINE	3.346	2.997	5.5	2.28	
ARGININE	9.853	10.295	5.5	4.99	
THREONINE*	2.291	2.030	3.63	4.01	4.0
ALANINE	4.216	4.447	5.72	3.75	
PROLINE	4.812	4.833	6.49	3.25	
TYROSINE	3.941	4.108	4.07	2.94	
VALINE*	4.812	4.785	4.51	5.41	5.0
METHIONINE*	2.200	2.513	1.76	1.04	3.5
CYSTEINE	0.275	0.193	2.31	0.09	
ISOLEUCINE*	4.491	4.350	4.29	4.06	4.0
LEUCINE*	6.279	6.187	13.75	7.1	7.0
PHENYLALANINE*	4.629	4.592	3.63	4.96	6.0
LYSINE*	6.233	6.670	3.41	5.87	5.4

*Essential amino acids

The protein digestibility of the 2 varieties grown in Uganda was found to be around 72% but roasting and popping, the two commonly-used preparation methods, were found to reduce digestibility to 60.6% and 52.5%, respectively. The level of tannins, an anti-nutrient known to reduce protein digestibility, in the grain amaranth varieties grown in Uganda was found to range from 0.11% catechin equivalent to 0.42%, which is higher than the levels in other grains like millet and sorghum. The level varied with the geographical area where the amaranth was grown. The levels of other nutrient inhibitors such as hemagglutinin, trypsin inhibitor and saponins in amaranth have been reported to be within the non-critical range (Escudero *et al.*, 1999).

The carbohydrates in amaranth grain consist primarily of starch made up of both glutinous and non-glutinous fractions. Amaranth starch granules are much smaller (1-3 μm) than those found in other cereal grains (Teutonico and Knorr, 1985). Due to the unique size and composition of amaranth starch, the starch may exhibit distinctive characteristics which could be of benefit to the food industry (Lehman, 1988). Amaranth starch seems to have potential for use in the preparation of custards, pastes and salad dressing (Singhal and Kulkarni, 1990a, b).

Amaranth grain obtained from farmers in Kamuli was found to contain 6.9-7.4% oil (Table 1) and the oil was made up predominantly of unsaturated fatty acids, with high levels of the essential fatty acid linoleic acid (Table 4). Based on its fatty acid profile, it can be concluded that grain amaranth is reasonably safe for consumption by individuals that are at high risk of chronic non-communicable diseases such as coronary heart disease and diabetes. Its high content of linoleic acid, an essential fatty acid, makes it suitable for consumption by children since they need essential fatty acids for proper growth and development.

Table 4: Fatty acids profile for grain amaranth from Kamuli, Uganda

Fatty acid	Content (mg/g)	
	White	Golden
Palmitic acid	1.92	2.31
Stearic acid	0.17	0.21
Oleic acid	2.19	1.92
Linoleic acid	2.8	2.41

PROCESSING OF GRAIN AMARANTH

The procedures used in the processing and preservation of amaranth seeds in Uganda are quite similar to those documented elsewhere. In this section, a general description of the methods used in processing grain amaranth is provided and the processes or conditions peculiar to Uganda are highlighted. The influence of some processing treatments on nutritional quality and acceptability are also described.

Grain preparation

When the mature amaranth seeds are harvested, they are dried in the sun, winnowed and stored until ready for use. Grain amaranth should be dried to a moisture content not exceeding 12% to limit mold growth. It is also important to clean the grains since the presence of vegetative material in the grain also encourages mold growth. Mold growth is particularly undesirable because it leads to the accumulation of mycotoxins which are carcinogenic. It is also important to store the grain on raised pallets in containers that allow for heat and moisture exchange. Sisal bags, which are widely used for grain storage in Uganda, are quite suitable for storage of grain amaranth. To maintain grain quality and to prevent loss, it is also important to prevent attack by pests and rodents. Storage pests such as weevils and grain borers do not commonly attack the amaranth grains, and therefore post-harvest losses are minimal if storage is under the conditions described above.

Heat treatment

Processing of amaranth seeds involves heat treatment (popping, toasting/roasting), sprouting and milling. Heat treatment helps to overcome milling problems due to the small size of the amaranth seeds; it also takes away the grittiness of the seeds (Oke, 1993). It may be done by popping and toasting/roasting.

Popping of amaranth seeds is normally done in a large, hot pan at a high temperature (an air temperature of about 220°C for 10 – 15 seconds). The seeds are stirred constantly while popping to prevent them from burning and to allow most of them to pop (Teutonico and Knorr, 1985). Popping of amaranth seeds results in an increase in volume (Figure 3) of up to 1,050 % and gives the grains a gritty flavour (Saunders and Becker, 1984). The increased volume makes milling easier. In Uganda, popping is done using an open fire. The seeds are put on a pre-heated pan and the seeds stirred until the majority are visibly popped.

Figure 3: Popped amaranth seeds



Roasting/Toasting

Roasting/toasting can be done in an oven at around 200°C for 5 - 10 minutes. In rural Uganda, ovens are rare and toasted seeds are those that remain in the pan, un-popped, after open fire popping of amaranth seeds. The toasted seeds (Figure 4) are brownish and give a nutty flavour as well when milled.



Figure 4: Toasted/Roasted amaranth seeds

To sprout grain amaranth, clean amaranth seeds are soaked in water overnight at room temperature. The seeds are removed from the water and heaped on a tray, then covered with a clean towel to keep the seeds warm. After 2 days the sprouted seeds (Figure 5) are sun dried for 2 days. The dry seeds are rubbed together to get rid of the shoots (these give a bitter taste to the product made out of sprouted seeds), winnowed and the seeds stored (as described above under the preparation and storage section) until ready for milling into flour. Sprouting the seeds increases digestibility and bioavailability of nutrients.



Figure 5: Sprouted amaranth seeds

Milling

The seeds are milled into flour using a milling machine. In Uganda, some families pound the seeds in a mortar and pestle or grind them using a grinding stone. Pounding and grinding are done on a small scale and usually for a few meals to be consumed at home. This is because the flour quickly develops rancidity if it is kept for more than a month at room temperature. Amaranth keeps best when stored in airtight containers to prevent fat oxidation which contributes to rancidity. Families in Uganda store amaranth flour in airtight plastic containers or polyethylene bags (Figure 6) at room temperature and the flour can remain acceptable for 1-2 months.



Figure 6: Amaranth flour of (left to right): raw, roasted/toasted and popped seeds

The seeds are so small that sometimes some of them come out of the mill whole. Amaranth seeds are sometimes mixed together with cassava or other grains such as millet, maize and sorghum and these are milled together to make composite flour. The ratio of amaranth to millet, maize, sorghum or cassava varies according to individual taste and preference.

Utilization of Grain Amaranth

In Uganda, the products made out of amaranth seeds are soup, porridge, posho (stiff bread/porridge), paste (usually mixed with groundnuts) and pops; it is also used as a sauce thickener.

The SRL program has promoted the use of grain amaranth for feeding malnourished children. The amaranth is usually blended with other grains (mainly maize and millet) and given to children in the form of porridge. Amaranth-based porridge has also been adopted for the feeding of normal children as a complementary food, and for feeding the sick, including PLWHA. Feedback from the community shows a strong association of amaranth consumption and fast recovery from childhood malnutrition and reduced morbidity of PLWHA.

Experiments have been done on incorporating grain amaranth in snack foods commonly consumed by children in Uganda. Acceptable cakes and cookies have been developed with amaranth making up to 70% of the flour used. In other products such as *baggia* (a snack made by cold extrusion of dough followed by deep frying - see Figure 7) and *kabalagala* (a snack made by rolling dough into a flat shape, cutting into a round shape and then deep frying - see Figure 8), acceptable products were made with 100% amaranth flour.



Figure 7: Cold extrusion of dough for making *baggia*



Figure 8: Cutting of dough for making *kabalagala*

These snacks are commonly consumed by children in Uganda. Cookies, cakes and *baggia* are normally made from wheat flour while *kabalagala* is usually made from maize flour. By substituting the wheat or maize flour with amaranth, the protein content and quality as well as the iron, zinc, calcium and B-vitamins content of the snacks were improved. A study is underway to determine the effect on nutrient intake, nutritional status, morbidity and school attendance among school children of substituting the conventional snacks with similar snacks in which amaranth has been incorporated. Results so far show higher weight gain and improved school attendance among children aged 3-5 years snacking on amaranth-based cakes compared to those feeding on wheat-based snacks.

SUMMARY

From the work done so far, it is clear that grain amaranth has the potential to contribute to the improvement of the nutritional status of vulnerable populations such as children and the sick. By developing and promoting a variety of amaranth-based products, consumption of grain amaranth can be increased beyond non-producing communities. Promotion of value-added products can also contribute to expanding the market for amaranth. The next steps will therefore include promotion of value-added products, especially those suitable for feeding nutritionally-vulnerable people.

ACKNOWLEDGEMENTS

Part of this findings reported in this chapter were as a result of work undertaken with funding from the Nestlé Foundation, Switzerland to whom we are very grateful. We also acknowledge the contribution of Iowa State University.

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