



NUTRITIONAL VALUE AND UTILIZATION OF AMARANTHUS (*AMARANTHUS* SPP.) – A REVIEW

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ABSTRACT

Amaranth consists of 60-70 species, 40 of which are considered native to the Americas. They are grown in the temperate and tropical climates, and are used as grain or vegetable. They are highly nutritious, contain vitamins and minerals. The leaves, shoots, tender stems and grains are eaten as pot herb in sauces or soups, cooked with other vegetables, with a main dish or by itself. The plants are used as forage for livestock. Traditionally, the boiled leaves and roots are used as: laxative, diuretic, anti-diabetic, antipyretic, anti-snake venom, antileprotic, anti-gonorrhoeal, expectorant, to relieve breathing in acute bronchitis. It also has anti-inflammatory properties, immunomodulatory activity, anti-androgenic activity and anthelmintic properties.

Keywords: Amaranth, species, nutritional value, anti- nutritional factors, nitrates

INTRODUCTION

Amaranthus species are a highly popular group of vegetables that belong to different species (Costea and Sanders, 2001; Grubbens, 1977; Grubbens and van Sloten, 1981; Sauer, 1976). Some of the most widely grown species include: *Amaranthus blitum* L. {Amaranth, wild amaranth, pigweed, purple amaranth (English), Amarante, sauvage, amarante blette (French), Amaranto, bredo (Portuguese)}; *Amaranthus dubius* Mart. Ex Thell. {Amaranth, pigweed (English), brede de Malabar (French), Amanto, bredo (Portuguese)}; *Amaranthus cruentus* L. {Amaranth, African spinach (English), Amarante, brede de Malabar (French); amaranto, bredo (Portuguese)}; *Amaranthus graecizans* L. {wild amaranth, prostrate amaranth, spreading pigweed (English), a Amaranth sauge, amarante sylvestris, amarante africaine (French), Trites, amaranto, bredo (Portuguese)}; *Amaranthus hypochondriacs* L. {Prince's feather, amaranth (English), Amarante, brede Malabar (French), Amaranto, bredo, (Portuguese)}; *Amaranthus spinosus* L. {Spiny amaranth, prickly amaranth, spiny pigweed (English), Amaranth epineuse, epinard Malabar, epinard piquant (French), Amarantho, bredo (Portuguese)}; *Amaranthus thunberch* Moq. (Wild amaranth, wild spinach, pigweed (English), Amarante sauvage, (French), Amaranto, bredo (Portuguese)}; *Amaranthus tricolor* L. {Amaranth, Joseph's coat (English), Amarante, brede de Malabar (French), Amarantho, bredo (Portuguese)}; and *Amaranthus viridis* L. {Green amaranth, local tote, African spinach (English), Amarante vertex, epinard vet, epinard du Congo (French), Amaranto (Portuguese)}. Many of them are cosmopolitan and occur in the tropics subtropics and worldwide (Baquar and Olusi, 1988; Brenan, 1981; Chweya, and Eyzaguirre, 1999; Grubbens and Denton, 2004; Schippers, 2002; Townsend, 1985; Van Epenhuijsen, 1974).

A. cruentus and *A. hypochondriacus* are the grain type, while the rest are the vegetable type. Both leaves and seeds contain protein of an unusually high quality. The grain is milled for flour or popped like popcorn. The leaves of both the grain and vegetable types may be eaten raw or cooked. Amaranths grown principally for vegetable use have better tasting leaves than the grain types. Amaranth consists of 60-70 species, 40 of which are considered native to the Americas. Over 400 varieties within these species are found throughout the world in both temperate and tropical climates, and fall roughly into one of four categories: grain, vegetable, ornamental or weed. Many fall into more than one. Vegetable amaranth has been used in China for over 400 years, yet is commonly found in the Caribbean and Africa; grain amaranth was cultivated and revered by the Aztecs in Mexico, the Mayas in Central America and the Inca in South America (O'Brien and Price, 2008). In Nigeria especially Yoruba community all species are referred to as "tete" even though they may add a second name to indicate a particular variety or species. The Hausas refers to them as "alayaho while Igbos call them "imne".

NUTRITIONAL VALUE

Amaranthus is highly nutritious, both the grain amaranth and leaves are utilized for human as well as for animal food (Tucker, 1986). The species vary slightly in their nutritional value and chemical composition as stated in Table 1. The nutritional value of amaranth has been extensively studied (Becker *et al.*, 1981; Teutonico and Knorr, 1985; Martirosyan, 2001 and Martirosyan, 2003). It has been shown that amaranth leaves are excellent sources of protein, with its maximal accumulation in the blossoming phase (Kadoshnikov *et al.*, 2005) (17.2–32.6% from dry weight for various samples).

Grain Amaranth: Grain amaranth has higher protein than other cereal grains and has significantly higher lysine content (Bressani, 1989; Lehman 1989). It has more protein than maize, and the protein is of an unusually high quality (high in the amino acid lysine, which is the limiting one in cereals like maize, wheat and rice). The protein is also relatively rich in the sulphur-containing amino acids, which are normally limited in the pulse crops. The "protein complement" of grain amaranth is very near to the levels recommended by FAO/WHO (O'Brien and Price, 2008). Amaranth grain consists of 6 to 10% of oil, which is higher than most other cereals. Amaranth oil contains approximately 77% polyunsaturated fatty acids which are mostly within the germ (Whelton, 1997; Betschart *et al.*, 1981; Lorenz and Hwang, 1985). Amaranth oil is predominantly unsaturated oil which is high in linoleic acid (about 50%), which is necessary for human nutrition. Yanez *et al.* (1994) showed that oil extracted from *Amaranthus cruentus* contained 19% palmitic acid, 3.4% stearic acid, 34% oleic acid and 33% linoleic acid. Docosaenoic acid (C22: 1) was present at the level of 9%. The ratio of saturated to unsaturated fatty acids was approximately 1:3. The lipid fraction is unique due to such high biologically active compounds, such as: squalene (up to 8%), tocopherols (to 2%), phospholipids (to 10%), and phytosterols (to 2%). Detailed studies on amaranth grain oil have been researched further in the last 2–3 decades (Lyon and Becker, 1987; Yorge, 1992; Martirosyan *et al.*, 1994; Pogojeva *et al.*, 2006). The use of cooked or autoclaved amaranth grain for use as chicken feed, gave production results comparable to those from feeding corn/soybean ration (Acar *et al.*, 1988). Processed amaranth (*A. hypochondriacus*) grain is a potentially useful energy supplement for broiler diets and can be incorporated at levels up to 400 g per kg without adverse effects (Ravindran *et al.*, 1996). Amaranth also solves the problems of formulating hog feed without using often prohibited animal protein. Zraly *et al.* (2004) utilized the quality of the amaranth protein, particularly because of the amino acid lysine, to formulate a complete feed ration using both grain and plant biomass to successfully fatten hogs. *A. hybridus* and *A. retroflexus* have been successfully incorporated into feed for calves and sheep as forage, with the results obtained not significantly different from that of alfalfa. Leaves from *A. cruentus* provide balanced forage high in crude protein, low in cellulose and toxic substances (Pond and Lehmann, 1989). It is recommended as a suitable substitute for conventional forages such as alfalfa as an energy source for growing lambs at levels of up to 50% of diet. Amaranth also has high potential as forage for ruminants.

Human consumption: Amaranth leaves, stems and entire plants may be eaten raw or cooked as spinach or greens. Cooking and discarding the water removes potentially harmful oxalates and nitrates. Boiling and squeeze washing lead to more loss than blanching especially vitamin c content (Babalola *et al.*, 2010). In African countries, amaranth is an important nutritious food in regards to treating those suffering from

HIV/AIDS. On a poor diet, the anti-retroviral drugs function poorly or not at all. Often, the drug becomes a toxin in itself. Amaranth grain porridge (1 cup) combined together with moringa leaf powder (1 Tbsp) from moringa leaves (*Moringa oleifera*) provide not only an excellent nutritional food for the AIDS sufferer, but those consuming the amaranth/moringa combination are able to take anti-retroviral drugs with no complications. Alternatively, amaranth seeds can be popped like popcorn. Amaranth can be used: in confections bound with sorghum, molasses or honey, in high-energy granola and granola bars, in cheese spreads, as a condiment to flavor salad dressings, in breading for chicken and fish, in crackers, pie crusts and breads, and as toppings for casseroles and desserts (O'Brien and Price, 2008).

UTILIZATION OF VARIOUS SPECIES

A. blitum: Is used as a leaf vegetable in most African countries where it is collected as a pot herb from the wild. It is very much liked for its soft taste and is recommended as a good food with medicinal properties for young children, lactating mothers and for patients with fever, hemorrhage, anaemia and kidney complaints (Grubbens and Denton, 2004). The leaves are used as a febrifuge and poultice to treat inflammations, boils, abscesses and lung disorders. Used as fodder for livestock, but only as moderate part of the daily portion or ration (Grubben and Denton, 2004). The seeds are used to make an intoxicating drink in south-western Africa (Burkill, 1985). Some of the drawbacks are: contains anti-nutrients (nitrates, oxalates) which makes it less suitable for consumption, but are removed by adequate cooking (Senft *et al.*, 1981).

A. dubius: As a vegetable (alone or mixed with bitter leaf or nightshades). Used for children and lactating mothers, treating fever, haemorrhage, anaemia, stomach ache and for making potash (Grubbens and Denton, 2004; Schippers, 2002). The drawback is that it contains hydrocyanic and oxalic acids (removed by adequate cooking) which make it less suitable for human consumption and fodder for animals (Oomen, 1971; Oomen and Grubbens, 1978).

A. cruentus: The protein has a high content of sulphur containing amino acids (methionine and cysteine), which make it a good combination with cereals. It is used mainly as a leaf vegetable, prepared by cooking and consumed as a vegetable dish or as an ingredient in sauces. The leaves and tender stems are cooked or fried in oil and mixed with meat, fish, curcubit seeds, groundnut and palm oil. This is eaten with the main dish of cereals or tubers. The powdered dry leaves are used in sauces during the dry season (Grubbens and Denton, 2004). In South Africa, it is grown commercially for canning and sold in supermarkets. In some other countries they are grown as ornamentals, for fodder, and for making dye. In Benin Republic, the dried plant is burnt for the preparation of potash. Medicinally it is used as follows: for young children and lactating mothers, for treating constipation, anaemia, kidney complaints, roots are boiled with honey as a laxative for infants, its water extract is used to treat pains in the limbs,

as a tape worm expellant, wound dressing and tumours; has antioxidant properties; used industrially-lubricants in computer industry, cosmetics and health foods (Grubbens and Denton, 2004; Oomen, 1971; Oomen and Grubbens, 1978; Schippers, 2002). The drawback is that it contains hydrocyanic and oxalic acids which make them less suitable for human consumption but these properties are removed by adequate cooking.

A. graecizans: Leaf vegetable, and pot herb in many countries. It is eaten mixed with other wild vegetables such as *Solanum*. The seed is baked into thin cakes while in some countries it is ground into flour. In East and West Africa, the plant is used to manufacture a local salt. Liquid extracts from the plant is used to treat tonalitis and anthelmintic. The drawback is that it has a bitter taste and the leaves are small (Grubbens and Denton, 2004; Oomen, 1971; Oomen and Grubbens, 1978; Schippers, 2002). It contains some toxic substance, which is removed by adequate cooking.

A. hypochondriacus: Used a potherb, and the seed as grain (South and Central America and Asia). The seed is pooped, roasted or milled like maize; used to make bread in India, while in Africa, it grown as an ornamental; recommended as health food; has antioxidant properties; the starch granules in it makes useful in industries- lubricants in the computer industry and cosmetics (Grubbens and Denton, 2004, Schippers, 2002). The oil contains squalene (He *et al.*, 2002; 2003; He and Corke, 2003). The squalene concentration in the oil ranges from trace to 7.3% is much higher than in other oilseeds. Squalene, a steroidal hormone precursor is used for cosmetics and it's employed as lubricant for precision instruments, such as computer disks (Budin *et al.*, 1996). It was also reported that this compound has important beneficial effects on cancers (Rao and Newmark, 1998) and reduces cholesterol level in the blood (Smith, 2000; Miettinen and vanhanen, 1994). *Amaranthus* seed has been suggested as an alternative to marine animals as a natural source of squalene (He *et al.*, 2002). *A. hybridus* seed oils can be considered as source of n-3 polyunsaturated fatty acid (PUFA). The omega-3 polyunsaturated, docosahexaenoic acid (DHA) plays a number of biologically important roles, particularly in the nervous system, where it is found in very high concentrations in cell membranes. In infants, DHA is required for the growth and functional development of the brain, with a deficiency resulting in a variety of learning and cognitive disorders (Dheltot *et al.*, 2006). During adulthood, DHA maintains normal brain function and recent evidence suggests that reduced DHA intake in adults is linked with a number of neurological disorders including schizophrenia and depression. n-3 polyunsaturated fatty acids may protect against vascular diseases, however, their high accumulation in membranes may increase lipid peroxidation and subsequently induce deleterious effects in patients suffering from oxidative stress (Turner and Else, 2003).

A. spinosus: Leaves and stems collected, cooked, steamed or fried and consumed. They are also sold in

the market, but it attracts lower price. It has a bitter taste and is usually eaten in small quantities as substitute for other vegetables. It is used as forage for livestock; the ash is a tenderizer in cooking tough vegetables and pigeon peas; the ash is used as salt; the root is an effective diuretic; to treat gonorrhoea; an emmenagogue, emollient and antipyretic; applied externally to treat eczema, burns wounds, boils, earache and haemorrhoids; treatment of sores, ophthalmia and convulsions; as an expectorant; as a sudorific, febrifuge, antidote to snake bite poison, galactagogue; treatment of menorrhagia.

Traditionally boiled leaves and roots of *A. spinosus* are given to children as laxative. However, the concoction is also used traditionally as diuretic, anti-diabetic, antipyretic, anti-snake venom, antileprotic, and anti-gonorrhoeal (Kirtikar and Basu, 1987). In Malaysia, it is used as an expectorant and to relieve breathing in acute bronchitis. Some tribes in India apply *A. spinosus* to induce abortion (Grubbens & Denton 2004). It is reported for its anti-inflammatory properties (Olumayokun *et al.*, 2004), the effect on hematology (Olufemi *et al.*, 2003), and immunomodulatory activity had been reported (Tatiya *et al.*, 2007). It has anti-androgenic activity (Murgan *et al.*, 1993a), anthelmintic properties (Assiak *et al.*, 2002) and effect on biochemical changes in epididymis (Murgan *et al.*, 1993b). The drawback is that the plant has spines that can cause injury to the mouths of grazing animals and few cases of poisoning in cattle have been reported; it induces abortion and may cause renal failure. In addition it contains carbohydrates specifically useful in biochemistry; has strong phagocytic effect; has fungal activities against *Cercospora cruenta*; has anti-viral activity against Aujeszky virus (ADV) in IB-RS-2 pig cell cultures and bovine diarrhoea virus (BVDV) in GBK bovine cell lines; extracts from leaves inhibit germination of seeds of carrot, onion and tomato (Grubbens and Denton, 2004; Katende *et al.*, 1999; Schippers, 2002).

A. thunbergii: Eaten fresh or dried with milk or fat in combinations with maize or sorghum; eaten with a porridge of pearl millet; is a potherb; fodder for livestock; ground and dried flower heads are used to make tobacco snuff milder (Oomen, 1971; Oomen and Grubbens, 1978). The drawback is that it is a bitter in taste and contains anti-nutrients (nitrates, oxalates)- these are removed by adequate cooking; it contains hydrocyanic acid and oxalic acid which makes it less suitable for human consumption (Grubbens and Denton, 2004; Schippers, 2002).

A. tricolor: Used as cooked leaf vegetable; eaten raw with salads; the soft stem are eaten as asparagus; as an ornamental; treatment of inflammations and internally as a diuretic (Grubbens and Denton, 2004; Oomen, 1971; Oomen and Grubbens, 1978; Schippers, 2002). Some of the drawbacks are: it contains anti-nutrients (nitrates, oxalates) - these are removed by adequate cooking; contains hydrocyanic acid and oxalic acid, which make it less suitable for human consumption (Grubbens and Denton, 2004; Oomen, 1971; Oomen and Grubbens, 1978; Schippers, 2002).

A. viridis: Sometimes eaten as cooked vegetable; fodder for cattle and green manure; the leaves are diuretic and purgative as well as in poultices (fresh or as dried powder) for treating inflammations, boils and abscesses, gonorrhoea, orchitis and haemorrhoids; its infusion is used to purify blood; the pounded root is applied against dysentery; leaf sap is used as an eye wash to treat eye infections, convulsions and epilepsy in children; the sap is used as vermifuge against filarial, asemmanogogue and to relieve heart troubles; the leaves have febrifugal properties; rich in soda and is used in soap making; the powdered leaf contains reducing sugars and resins that have allelopathic effects on lettuce seed germination (Grubbens and Denton, 2004; Oomen, 1971; Oomen and Grubbens, 1978; Schippers, 2002).

GENERAL USES

Vegetable amaranth has received significantly less research attention than grain amaranth. However, it has been rated considerably higher in minerals, such as calcium, iron, phosphorous (Makus and Davis, 1984; Igbokwe *et al.*, 1988) and carotenoids (Martirosyan *et al.*, 2004) than most vegetables. Pharmacological properties of different amaranth species also have been investigated. It was determined that *Amaranthus paniculatus* and *Amaranthus cruentus* are good sources of flavanoids, especially for rutin, which are mostly produced in the stage of blossoming (Martirosyan *et al.*, 2003). Usage of amaranth as livestock feed indicated relatively high protein qualities (Sanchez *et al.*, 1990; Kadoshnikov *et al.*, 2001; Sleugha *et al.*, 2001).

The leaves, shoots and tender stems are eaten as a potherb in sauces or soups, cooked with other vegetables, with a main dish or by itself. The seed/grain are also edible. Chopped plants have been used as forage for livestock. It was reported through the ECHO network that goats fed amaranth forage consistently bore twins! And, the flowers are nice ornamentals, fresh or dried. Amaranth is not in the grass family, therefore is not considered a cereal grain. However, since it is used much like cereal grains, and is often called a pseudo cereal. Like other small grains, amaranth may be processed in popped, flaked, extruded and ground flour forms (O'Brien and Price, 2008). In Mexico, the popped amaranth confection, 'alegría' is a popular favorite among locals and tourists. The flour or flaked forms are combined with wheat or other flours to make bread, cereals, cookies and other baked goods. Amaranth used to make up only 10-20% of the flour blend, but it can be blended at 50-75% levels and still maintain functional properties and flavor. Coarsely ground amaranth is used to make a tasty and nutritious porridge cooked by itself or mixed with other grains and pseudo cereals such as oats (*Avena spp.*), wheat (*Triticum spp.*), milled flax seed (*Linum usitatissimum*), wheat germ, and cañihua (*Chenopodium pallidicaule*). Other seed components with useful potential include anthocyanin (red) pigments to produce non-toxic natural dyes, microcrystalline starch for food and industry and squalene, specialized oil used in skin

cosmetics, computer and pharmaceutical industries (O'Brien and Price, 2008).

Several studies have shown that like oats, amaranth seed or oil may be of benefit for those with hypertension and cardiovascular disease; regular consumption reduces blood pressure and cholesterol levels, while improving antioxidant status and some immune parameters (Czerwiński *et al.*, 2004; Gonor *et al.*, 2006; Martirosyan *et al.*, 2007). While the active ingredient in oats appears to be water-soluble fiber, amaranth appears to lower cholesterol via its content of plant stanols and squalene.

TOXIC ASPECTS OF AMARANTHUS

Lehmann (1992), in a review article, identifies some of these reported anti-nutritional factors in amaranth to be phenolics, saponins, tannins, phytic acid, oxalates, protease inhibitors, nitrates, polyphenols and phytohemagglutinins. Of these, oxalates and nitrates are of more concern when amaranth grain is used in foraging applications. Some studies suggest thermal processing of amaranth, particularly in moist environment, prior to its preparation in food and human consumption may be a promising way to reduce the adverse effects of amaranth's anti-nutritional and toxic factors.

Nitrate Accumulation & Poisoning: Nitrate is a simple form of nitrogen. Plants absorb nitrates from the soil and convert them into more complex forms of nitrogen, such as proteins. Amaranthus is one of the plants that accumulate nitrates especially when soil fertility is very high (generally the result of adding nitrogen fertilizer), and when something slows the process of photosynthesis, such as herbicide, drought, or frost. Nitrates are accumulated mainly in the plant tissues and not in the seeds. Human infants and some animals have bacteria in their digestive systems, which convert nitrates to nitrite. In humans, by six months old, the acid levels in the digestive system rise higher and kill these bacteria, and the danger of nitrate poisoning is unlikely, although if a woman is pregnant and is being treated for cancer, or has low stomach acidity, there is increased risk (O'Brien and Price, 2008).

Nitrites bind to the hemoglobin in blood, robbing it of the ability to carry oxygen. Since hemoglobin's function is to carry oxygen, the net effect is oxygen starvation. Hence the symptoms of nitrite poisoning include shortness of breath and reduced immunity to disease, and, in extreme cases, may lead to death from suffocation. This is the cause of 'blue baby syndrome'. Livestock, though, are frequently poisoned by high nitrate levels in food, possibly due to the lack of variety in their diet (O'Brien and Price, 2008). Nitrates also combine with some proteins to make nitrosamines, which may cause cancer. People who are over six months old, healthy, and have a good diet, probably don't have to worry too much about nitrates in their food (O'Brien and Price, 2008). The raw amaranth grain contains toxins and anti-nutritional factors that can reduce its effectiveness as an animal feed. Scientists in Australia fed raw amaranth grain to poultry as the major component of the diet.

As a result the chickens went into convulsions and died. An unidentified toxic factor had caused liver damage leading to the death of the chickens (Cheeke and Bronson, 1980).

PROSPECTS FOR FURTHER RESEARCH

More research is needed into the nutritional aspect and utilization of the different species of *Amaranthus*;

research into some of the medical uses need further confirmation and elucidation; breeding of *Amaranthus* for very low level of oxalates, nitrates and other poisonous substances is needful; grain amaranth species that have high level of protein should be promoted in developing countries as a source of protein; breeding for high grain and/or leaf yield will be helpful to farmers.

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Table 1. Nutritional composition of various species of Amaranthus (per 100 g of edible portion).

Chemical composition	Amaranthus species									
	<i>A. blitum</i>	<i>A. dubius</i>	<i>A. cruentus</i>	<i>A. graecizans</i>	<i>A. spinosus</i>	<i>A. hypochondriacus</i>	<i>A. thunberg</i>	<i>A. tricolor</i>	<i>A. viridis</i>	
Water (g)	88.9	84	84.0	84	84	84	84	88.9	88.9	
Energy (Kcal)	18	42	42	42	42	42	42	18	18	
Protein (mg)	3.5	4.6	4.6	4.6	4.6	4.6	4.6	3.5	3.5	
Fat (g)	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	
CHO (g)	0.3	8.3	8.3	8.3	8.3	8.9	8.3	0.3	0.3	
Fibre (g)	2.6	1.8	1.8	1.8	1.8	1.8	1.8	2.6	2.6	
Ca (mg)	270	419	410	410	410	410	410	270	270	
Mg (mg)	130	-	-	-	-	-	-	130	130	
P (mg)	65	103	103	103	103	103	103	65	65	
Fe (mg)	3.0	8.9	8.9	8.9	8.9	8.9	8.9	3.0	3.0	
Carotene (µg)	1725	5716	5716	5716	-	5716	5716	1725	1725	
Thiamine (mg)	0.07	0.05	0.05	0.05	-	0.05	0.05	0.07	0.07	
Riboflavine (mg)	0.22	0.42	0.42	0.42	-	0.42	0.42	0.22	0.22	
Niacin (mg)	0.7	1.2	1.3	1.2	-	1.2	1.2	0.7	0.7	
Folate	85	-	-	-	-	-	-	85	85	
Ascorbic Acid (mg)	42	64	64	64	-	64	64	42	42	

Sources: Holland *et al.*, 1991; Leung *et al.*, 1968