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Nutrient management and nutritive value of pseudo cereals: A review

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Abstract
Pseudocereals are multi-purpose crops cultivated for their high nutritional quality as a food and animal feed. In botanical terms, amaranth, quinoa and buckwheat are not true cereals, they are dicotyledonous plants as opposed to most cereals (e.g. wheat, rice, barley) which are monocotyledonous. They are referred to as pseudocereals, as their seeds resemble in function and composition those of the true cereals. Among the pseudocereals, amaranth have been cultivated for their grains and grown for their edible seeds rich in starch. Countries that grow grain amaranth in significant quantities include Mexico, Russia, China, India, Nepal, Argentina, Peru and Kenya. It grows very rapidly, especially under conditions of high temperatures, water scare conditions. In India, Amaranth is cultivated in the hilly regions as well as in the plains, covering the entire Himalayan region, Southern India and in some parts of a Western and Northern India. Amaranth grain is reported to have high levels of lysine, a nutritionally critical amino acid ranging from 0.73 to 0.84% of the total protein content and the grain is high in fiber and low in saturated fats. In irrigated areas, amaranth provides an alternative for farmers as it consumes less water and reduce the potential for sod salinization. Quinoa is a stress-tolerant plant, cultivated along the Andes, from about 3000 B.C and is still cultivated in Peru, Bolivia, Chile, Ecuador, Colombia and Argentina. Its grains have a high-protein content with abundance of essential amino acids, and a wide range of vitamins, minerals and saponin and it is a promising worldwide plant for human consumption and nutrition.

Keywords: Nutrient, management, nutritive, pseudo, pseudocereals

Introduction
Amaranth have been cultivated for their grains for 8,000 years (O'Brien and Martin 1983) [26] and are classified as pseudo cereals that are grown for their edible seeds rich in starch, but they are not in the same botanical family as that of rice and wheat. Countries that grow grain amaranth in significant quantities include Mexico, Russia, China, India, Nepal, Argentina, Peru and Kenya. It grows very rapidly, especially under conditions of high temperatures, water scare conditions. The leaves of several species of amaranth are valued as vegetables in many parts of the world, including South America, Asia and Africa, and where multi-cropping is practiced young leaves are harvested several times before plants flower and fruit. The fruits are then harvested as a grain crop. Interest in the possible development of grain amaranth as an important food crop was revived in the 1970s. Most grain amaranth is consumed as a popped cereal mixed with molasses, but it can be milled into a flour for inclusion in bread and other baked products. Grains reportedly contains twice the level of calcium in milk, five times the level of iron in wheat, higher potassium, phosphorus and vitamins A, E, C and folic acid than cereal grains

In India, Amaranth is cultivated in the hilly regions as well as in the plains, covering the entire Himalayan region, Southern India and in some parts of a Gujarat, Maharashtra, Orissa and Eastern UP (Bhag 1994) [4]. Amaranth grain is reported to have high levels of lysine, a nutritionally critical amino acid ranging from 0.73 to 0.84% of the total protein content (Bressani *et al.*, 1987) [7] and the grain is high in fiber and low in saturated fats. In irrigated areas, amaranth provides an alternative for farmers as it consumes less water and reduce the potential for sod salinization (Weber *et al.* 1988). In mid and higher Himalayan region the crop is cultivated widely by the resource poor farmers with very little inputs. The crop is generally grown by conventional methods and yield obtained thus is very low.

The other pseudocereals includes quinoa, domesticated chenopods and buckwheat. Quinoa (*Chenopodium quinoa* Willd.), is a stress-tolerant plant, cultivated along the Andes, from about 3000 B.C and is still cultivated in Peru, Bolivia, Chile, Ecuador, Colombia and

Argentina (Gonzalez *et al.*, 2012) [13]. Its grains have ahigh-protein content with abundance of essential amino acids, and a wide range of vitamins, minerals and saponin and it is a promising worldwide plant for human consumption and nutrition (Bilalis *et al.*, 2012) [7].

The cultivation of the pseudocereal especially amaranth gaining momentum in India and there exists a need for scientific nutrient management for realizing the potential or maximum grain yield. The number of studies on fertilization requirements of amaranth are limited, thus the authors reviewed the work on nutrient related studies and presented here under.

Nutrient Management in Grain Amaranth

In general, fertilization had a positive impact on growth and yield of pseudocereals. Nitrogen fertilization found to enhance the grain yield of amaranth in many environments (Elbehri *et al.*, 1993). Tayade (2012) [11, 33] reported that application of recommended dose of fertilizers with 10 tonnes per ha FYM, 5 tonnes per ha vermicompost, 5 kg per ha *Aztobacter* and 5 kg per ha PSB to amaranth found tobe a sound integrated nutrient management practice, as it recorded maximum plant height, number of leaves and grain yield. And also reported that total chlorophyll content was highest with the application of 50 percent recommended dose of fertilizer along with 5 tonnes per ha of vermicompost. Papastylianou (2014) revealed that fertilization with inorganic source had better results in amaranth.

Application of fertilizers *i.e.* 40 Kg N and 20 Kg P per ha along with FYM @ 5 t per ha gave significantly higher grain yields of 0.92 to 1.08 tonnes per ha (TejPratap and Manoranjan Dutta, 2010) [34]. Gunda Schulte auf'm Erley *et al*. (2005) [15] in their nutrient studies in pseudocereals with varying levels of nitrogen *viz.,*0, 80, and 120 kg N per ha for amaranth and quinoa and 0, 30, and 60 kg N per ha for buckwheat revealed that grain yield of amaranth responded to Nitrogen and yield ranged between 1986 and 2767 kg per ha. Quinoa yielded between 1790 and 3495 kg grain per ha and responded strongly to N fertilization whereas, the grain yield of buckwheat did not respond to N fertilization and yield averaged at 1425 kg per ha. Neeraja*et al* (2005) reported that application of 50% RDF + Vermicompost @ 2t per ha mixed with azetobacter+ PSB recorded higher grain and straw yields, test weight, protein content and higher net realization, while, application of 100% RDF + Vermicompost @ 1 t per ha resulted in higher lodging percentage.

Pratap and Dutta (2010) [34] obtained a higher yield of grain amaranth by the application of 40 Kg N and 20 Kg P per ha along with FYM @ 5 t per ha and suggested that application of organic fertilizer in combination with inorganic ones is essential to get maximum production in grain amaranth. Mahata and Sinha (2018) evaluated organic sources for nitrogen management in grain amaranthand obtained a highest yield of 16.9 q per ha in integrated nutrient management. Patel *et al* (2005) [29] obtained a higher grain yield of 1836 kg per ha over control by the application of 5 tonnes FYM ha^{-1} along with 100% RDF (60 kg N + 40 kg P_2O_5 ha^{-1}) resulted in higher net returns (Rs. 12,384 ha^{-1}). Shukla *et al*. (2012) [32] obtained a highest grain yield of amaranth (20.37 and 22.58 q/ha during 2007 and 2008, respectively) for the application of fertilizers 60 kg N and 40 kg P_2O_5 which was at par with vermicompost@ 2.5 t per ha + chullu cake 2.5 t per ha during both the years and this was found to be economical under rainfed condition.

The grain yield of quinoa was significantly increased by increasing N fertilization from 40 to 160 kg per ha, the yield response, however, was only moderate (Jacobsen *et al.*, 1994) [16]. Moreover, limited data are available regarding the fodder quality of quinoa and green amaranth crops. Bhargava *et al.* (2010) reported that the foliage of many species of Chenopodium is a rich source of minerals like potassium, sodium, calcium and iron and are rich in protein, carotenoid and ascorbic acid.

Table 1: Fertilizer recommendation for various soils and situations

Sl. No	Soil type / Situation	Inorganic fertilizers	Organic manures
1	Sandy clay soils	Nitrogen @ 30 kg/ha Phosphorus @ 30 kg/ha	Vermicompost + Azotobactor + phospjorus solubilizing bacteria
2	Loamy clay soil	Nitrogen @ 40 kg/ha Phosphorus @20 kg/ha	Farm Yard Manure @ 5 t/ha
3	Sandy soils	Nitrogen @ 60 kg/ha Phosphorus @40 kg/ha	Farm Yard Manure @ 5 t/ha
4	All Soils	---	Farm Yard Manure @ 10 t/ha + Vermicompost @ 5 t/ha + Azotobactor @ 5 kg/ha + PSB @ 5 kg/ha
5	Blanket recommendation (Tamil Nadu Soils)	Nitrogen @ 40 kg/ha Phosphorus @ 40 kg/ha Potassium @ 20 kg/ha	Farm Yard Manure @ 25 t/ha
6	Blanket recommendation (others)	Nitrogen @ 75 kg/ha Phosphorus @ 25 kg/ha	Farm Yard Manure @ 5 t/ha Azotobactor + phosphorus solubilizing bacteria

Nutrition and health benefits of Pseudo-cereals

Amaranth is one of the few multi-purpose crop which can supply grains and tasty leafy vegetables of high Nutritional quality as a food and animal feed. In botanical terms, amaranth, quinoa and buckwheat are not true cereals, they are dicotyledonous plants as opposed to most cereals (e.g. wheat, rice, barley) which are monocotyledonous. They are referred to as pseudocereals, as their seeds resemble in function and composition those of the true cereals. Amaranth seeds are small (1.5 mm diameter), they are lenticular in shape and weigh per seed is 0.6 to 1.3 mg (Bressani, 2003) [7]. Quinoa seeds are generally larger than amaranth, with a diameter of 1 to 2.5 mm (Taylor & Parker, 2002).

The use of alternative crops would result in product competitiveness, rich nutritional value, tradition, locality and special quality (Bavec and Bavec 2006).The crop produts are used for therapeutic purposes by local communities in different part of African (Kweninand Dzomeku 2011) [20]. Among the green leafy vegetable and cereals, *Amaranthus* species are regarded as store house for vital vitamins such as

vitamin C, B_6, folate and carotene (Musa *et al*. 2011). Mustafa *et al* (2011) [23, 24] reported that both the grain and leaves are utilized for human food as well as for animal feed as the crop has high levels of protein and minerals as compared to the commonly utilized cereal grains such as millet, sorghum, rice, wheat and corn. It also contains balanced essential amino acids and unsaturated fatty acids. Its protein is rich in lysine (sulfur-containing amino acids) a limiting amino acid that is absent in many other grains. (Amare *et al*. 2015) [2]. Protein content in amaranth and quinoa is generally higher than in common cereals such as wheat (Bressani, 1994) [7], and is usually highest in amaranth followed by quinoa and buckwheat. As a result, the amino acid composition of pseudocereal proteins is well balanced, with a high content of essential amino acids, and is thus superior to that of common cereals (Gorinstein *et al*., 2002). With regards to vitamin B content, amaranth is a good source of riboflavin and quinoa of riboflavin, thiamine and folic acid and buckwheat has a good content of thiamine, riboflavin and pyridoxine (Bonafaccia, Marocchini, and Kreft, 2003) [6].
The protein of grain amaranth has been claimed to be very near to the levels recommended by FAO/WHO because of balance in amino acid profile (Murya and Pratibha, 2018) [22]. The ability of these vegetables to promote health benefits is largely attributable to nutritional and bioactive compounds available in them (Cornejo *et al*. 2019) [8].

Table 2: Nutritive value of grain amaranth and other cereal grains.

Nutrients (%)	Crop					
	Amaranth	Millet	Sorghum	Rice	Wheat	Corn
Moisture	11.29	8.67	12.4	N.D	N.D	10.21
Protein	13.56	11.02	10.62	6.67	10.91	9.42
Lipid	7.2	4.2	3.46	2.22	1.82	4.74
Ash	2.88	3.25	N.D*	N.D	N.D	N.D
Carbohydrate	65.25	72.85	72.09	75.56	80	74.26
Fibre	6.7	8.5	6.7	2.2	2.2	N.D
Energy (kcal/100g)	371	375	329	356	364	365
Minerals(mg/100 g)						
Iron	7.61	3.01	3.30	1.11	3.27	2.17
Zinc	287	1.68	1.67	N.D	2.73	2.21
Magnesium	248	114	165	N.D	109	127
Manganese	3.3	1.6	N.D	N.D	N.D	N.D
Potassium	508	198	363	202	400	287
Calcium	159	8.0	13	4	36	7

*N.D: not determined. Source: Gebhardt *et al*. 2008 [12].

Amaranth proteins consist mainly of albumins and globulins, where prolamins, the toxic proteins for celiac patients, are very scarce. Amaranth grain is reported to have high levels of lysine, a nutritionally critical amino acid, ranging from 0.73 to 0.84% of the total protein content (Bressani *et. al* 1987) [7]. Amaranth leaves are also a wonderful astringent, and make a great wash for skin problems like eczema, and a wonderful acne remedy. Amaranth also makes an effective mouthwash for treating mouth sores, swollen gums, and sore throat. Amaranth leaves have been found to be a good home remedy for hair loss and premature graying. Studies have shown that regular consumption of amaranths has the potential to reduce cholesterol level, benefit people suffering from hypertension and cardiovascular disease (Olaniyi 2007; Kolawole and Sarah 2009) [27]. Amaranth grain has been found to provide alternative food ingredient in the development of food products other than wheat and cereals for celiac patients. The protein content of the leaves can vary between 17.2 and 32.6% on dry weight basis for various species (Murya and Pratibha, 2018) [22]. Besides, rich its nutritive value, amaranth grain contains bioactive compounds with health promoting effects (Karamac*et al*. 2019) [18].

Table 3: Chemical composition of amaranth, quinoa and buckwheat seeds.

Sl. No	Seed	Protein	Fat	Total starch	Dietary fibre	Ash
1	Amaranth	16.5	5.7	61.4	20.6	2.8
2	Quinoa	14.5	5.2	64.2	14.2	2.7
3	Buckwheat	12.5	2.1	58.9	29.5	2.1

Source: Alvarez-Jubete *et al*., 2010

Health benefits of Amaranth grain

1. Grain amaranthis a dicotyledonous seed and it is respected and employed like a cereal-grain in line with other staples like wheat and millets.
2. It contain many nutrients including essential amino acids, essential fatty acids, starch, fiber, minerals, and vitamins.
3. Amaranth grains carry the same levels of calories as any other legumes and pseudocereals like quinoa.
4. Amaranth grains carry 13-15 g of protein per 100 g. It composes almost all of the essential amino acids required for the human body at great proportions, especially in lysine which is a limiting amino acid in grains like wheat, maize, rice, etc.
5. Amaranth is one of the gluten-free staple foods. Gluten is a protein present in certain *grass family* grains like wheat, which may induce stomach upset and diarrhea in individuals with gluten sensitivity or celiac disease.
6. The grains are a rich source of soluble and insoluble dietary fiber.
7. Also, dietary fibers bind to bile salts (produced from cholesterol) and decrease their reabsorption in the colon, thus help lower serum LDL-cholesterol levels.
8. The quality of B-complex vitamins in amaranth grains is more superior to any cereals. Amaranth indeed an excellent composition of folates, niacin, thiamin, and pantothenic acid.
9. It is also an excellent source of vitamin-E (α-tocopherol).
10. The seeds are also a prominent source of essential fatty acids.

Table 4: Nutritional value of amaranth grain

Sl. No	Nutritional value per 100 g. (Source: USDA National Nutrient data base)	
	Principle	**Nutrient Value**
1	Energy	371 Kcal
2	Carbohydrates	65.25 g
3	Protein	13.56 g
4	Total Fat	7.02 g
5	Cholesterol	0 mg
6	Dietary Fiber	6.7 g
	Vitamins	

7	Folates (B9)	82 μg
8	Niacin (B3)	0.923 mg
9	Riboflavin (B2)	0.200 mg
10	Thiamin (B1)	0.116 mg
11	Vitamin-A	2 IU
12	Vitamin-E	1.19 mg
13	Vitamin-K	0
	Electrolytes	
14	Sodium	5 mg
15	Potassium	563 mg
	Minerals	
16	Calcium	159 mg
17	Iron	7.61 mg
18	Magnesium	248 mg
19	Phosphorus	557 mg
20	Selenium	8.5 μg
21	Zinc	2.87 mg

Anti-nutrient composition of amaranth grain

Amaranth said to contain anti-nutrients like phytate, saponins, tannins, oxalates, protease inhibitors and nitrates. Thus, the presence of anti-nutrients in amaranth grains may is a challenge for utilization as food stuff however, proper processing methods can minimize their anti-nutrient content. The effects of oxalates and phytates on nutrient inhibition are of more concern in amaranth grain. Dobos (1992) [10] found very low concentration of saponin (an average of 0.09%) in various amaranth species and also protease inhibitors (trypsin and chymotrypsin).These anti-nutritional elements serve protective effects in plants, for instance, phytic acid serves as a form of storage for phosphorus in the plants. But in humans, they inhibit nutrient absorption. Phytate is not digestible by humans and is therefore not a dietary source of inositol or phosphate. In addition, inhibition of starch digestion has been reported for phytate and oxalate. Saponins form complexes with mineral elements such as zinc and iron; oxalate binds calcium and thus reduces its absorption by cells (Cuadrado *et al*. 2019) [9].

Ways to minimize the anti-nutrient content

Different processing methods have been adopted to lower anti-nutrient contents of amaranth. Kanensi *et al*. (2011) [17] optimized the steeping and germination time for amaranth grain; steeping amaranth grain for 5 hours and germinating for 24 hours were recorded as the optimum processing times based on dry matter loss and reduction in anti-nutrient levels. Tannins are present in high concentrations in the grain hull, removal of the hull eliminates most of the tannins but this does not remove the phytic acid. Phytic acid is distributed uniformly in the grain, thus it cannot be reduced by abrasive removal of the external grain layers. Njoki (2015) examined the effects of dry heating processes (roasting at 160 °C for 10 minutes and popping at 190 °C for 15 seconds) and wet heating techniques (boiling whole grains at water: seeds of 4:1) and boiling amaranth flour at water: flour of 6:1) on important parameters of grains and reported that boiling of flour and whole grain increased the protein digestibility by 24% and 15% respectively, while roasting decreased the protein digestibility. Babatunde and Gbadamosi (2017) [3] explored the effects of five processing methods (defatting, blanching, germination, fermentation and autoclaving) on the protein digestibility and antinutrient composition of grains *Amaranthus viridis*. It was reported that germination at 30 °C for 72 hours has the most significant effect on protein digestibility; with 82% increase compared to fermentation which improved protein digestibility by 76%. Heat treatment such as autoclaving and blanching were more effective in reducing tannin and oxalate content.

Conclusion

Amaranth, the pseudo cereal crop yield around 1.0 to 1.5 tonnes per hectare in India with moderate application of fertilizer nutrients. However, higher yields can be achieved with improved varieties which are fertilizer responsive. In general nutrient management studies in amaranth revealed inclusion of organic in any form or adoption of integrated nutrient management system as it positively influence the quality and nutritional value of the grains. As per as the nutritional quality is concerned the pseudo cereals are generally rich in protein, minerals and vitamins which are superior to major cereal grains. This can be preserved through proper methods of food preparation and storage, however, there are some anti-nutritional components present in the grains and that can be lowered through proper processing and milling techniques.

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