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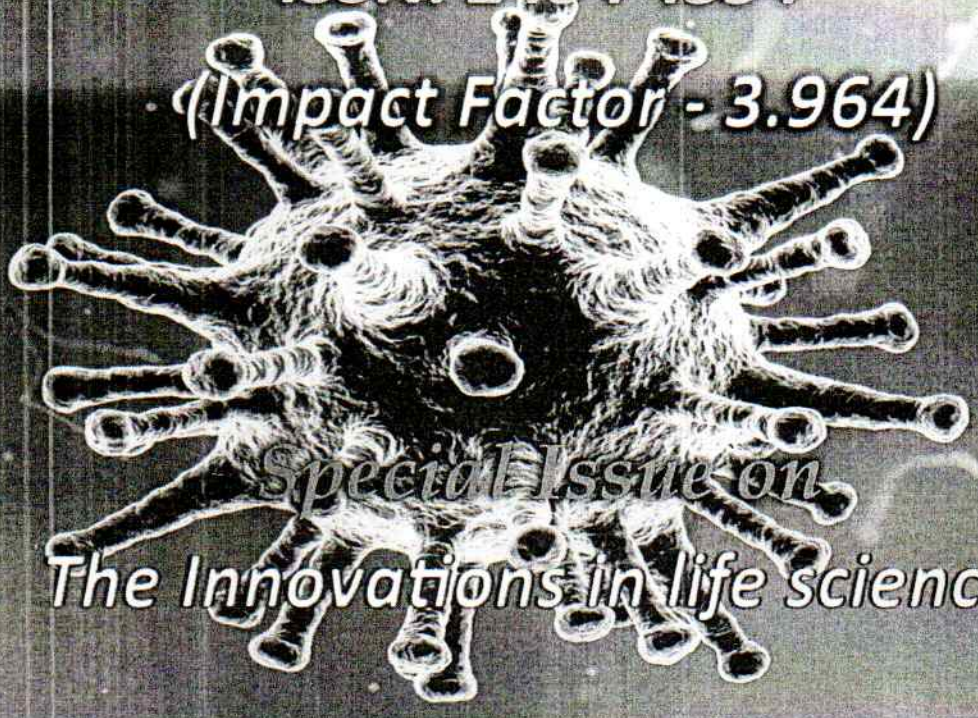

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CONTENTS

NUTRITIONAL QUALITIES OF *AMARANTH* SEEDS

R. Anitha [1] and P.A.Raajeswari[2]

[1,2]Dept of Food Science and Nutrition, Avinashilingam Institute of Higher Education for Women, Coimbatore.

Abstract

Amaranth, a third millennium crop plant, belongs to the family Amaranthacaea. The genus Amaranthus has more than 60 species distributed through out the world as grain crops, pot herbs, ornamentals and dye plants. It is one of the underrecognised, underutilized and understudied crops inspite of its vast growth as leafy vegetable in developing countries like India. Recent interest is being due to its high nutritive values than other cereal grains such as high protein (12 to 18%) especially lysine (5%) and sulfur amino acids 4.4%, higher concentration of soluble fibre, rich in unsaturated fatty acids especially linoleic acid, high oil content (1.5 to 3 %) with squalene (5 to 8%) contributing to cholesterol lowering effect., and contain substantial levels of essential micronutrients such as calcium, iron, sodium, and vitamin E. The Amaranth has relatively high starch content of small granule size, low amylose concentration, lower swelling power, low viscosity, high solubility, and low gelatinization temperature. Its unusual and unique nutritive composition makes it to use as a blending source to increase the biological value of processed food. For its brief growth cycle, capability to withstand unfavorable climate, use of entire plant along with its nutritive and functional importance, grain amaranth has the potential to contribute to the improvement of overall nutritional status in developing countries like India.

Introduction

Amaranth is a versatile, fast-growing cereal – like, an ancient plant belonging to the family Amaranthaceae. *Amaranth* is not a true cereal like wheat, rice, corn and barley. It is known as pseudo-cereal crop for both livestock feed and human nutrition. The genus *Amaranthus* consists of approximately 60 plant species of Amaranth, the majority of which are wild and weedy species native to tropical and temperate regions of the whole world but is most diverse in many areas like India, China, Africa, Central & South America and the United States (Stallknecht and Schultz-Schaeffer, 1993).Some of them are used as food (grain) others as ornamental (flower) and some are simple weeds with no use at all. Grain amaranth has now been rediscovered for its nutritional value, possibility of utilization of entire plant, its resistance to adverse climate and soil conditions, the study of this plant has being attracted a great interest by the food industry in recent decades. Its unusual and unique nutritive

composition makes it to use as a blending source to increase the biological value of processed food. The cooked grain has 90% digestibility and has been traditionally given to those recovering from illness of fasting period (Morales et al., 1988). Although many species of amaranth are considered as opportunistic weeds, only three species, A. hypochondriacus L., A.caudatus L. and A. cruentus L., are known to have light-coloured seeds and can be consumed by humans as a seed or used as functional ingredient in foods in India and other developing countries (Espitia-Rangel, 1994). The aim of this paper is to highlight the composition, properties and nutritive values of selected amaranth grain varieties.

***Amaranth* carbohydrates**

The carbohydrates in *Amaranth* grain consist primarily of starch made up of both glutinous and nonglutinous fractions. These fractions of Amaranth hypochondriacus has identified with starch granules consisting of nearly 100% typical amylopectin and 0 and 14% amylose, while Becker *et al.* (1981) found 7.2% amylose. X-ray diffraction analysis of Amaranth hypochondriacus starches showed that they were identical to maize and rice starches, indicating A type crystalline structure. The Amaranth caudatus starch was reported to be completely nonglutinous (Okuno and Sakaguchi ,1982.,Sugimoto *et al*,1981), while A. cruentus starch was reported to be glutinous (McMasters *et al*., 1955).

Amaranth starch granules are small and lenticular in shape with diameters of 1.0–1.5mm, 1000-grain weight of 0.6-1.2 g, display an A-type X-ray pattern and low amylose content ranging from 3–8% depending on different genotypes (Choi *et al*., 2004; Hoover *et al.*, 1998., Marcone, 2001., Saunders and Becker, 1984). A similar study was also conducted by Xiangli Kong *et al* (2009) in China about the physical properties of amaranth starch, he reported that the amaranth starch had low but diverse amylose contents, ranging from 4.7% to 12.5%. Wide variation was found in physicochemical properties , such as swelling power, water solubility index, pasting, thermal and textural properties. Due to the unique size and composition of amaranth starch, it has been suggested that the starch may posses unique gelatinization and freeze/thaw characteristics which could be of benefit to the food industry (Becker *et al*. 1981; Lehman 1988).

Amy lose content is the most important factor affecting functional properties of amaranth starch. Physical properties of amaranth flour are quite different from those of wheat flour, the amaranth flour has high starch content (amylopectin 100% and amylase free) .Starch constitutes the main component of amaranth grain and plays an important role in its food applications, such as food thickeners for soups, fat replacers, gravies and sauces, and in breakfast cereals, muffins, cookies, snacks, pastas and health food. Other current and potential

commercial uses of amaranth starch are in cosmetics, biodegradable films, paper coatings and laundry starch (Choi, Kim, & Shin, 2004).

The starch content of pale-seeded grain types was reported to range from 48% for *Amaranth* cruentus and 62 % for *Amaranth* hypochondriacus The granules of starch isolated from the seeds of A. hypochondriacus were found to be small (1-3,um in diameter) and angular and polygonal in shape while those of A. cruentus were reported to be spherical as well as angular and polygonal (Saunders and Becker, 1984;.Stone and Lorenz, 1984). According to Goering (1967) *Amaranth* retropexus starch is composed of a small amount of small spherical granules and a large amount of irregular starch chunks. Physicochemical properties of chunk Amaranth retropexus starch suggested a homogeneous mass very strongly bound together but very susceptible to the attack of amylases.

Amaranth hypochondriacus has much a lower amylose content, a lower swelling power, a higher solubility, a greater water uptake, a lower amylograph viscosity, and a higher gelatinization temperature range compared to wheat starch.(Lorenz ,1981) Becker et al. (1981) suggested that the very small size of the starch granules and residual amylase activity were presumably responsible for the observed differences in swelling power and solubility. The higher viscosity of wheat starch after cooling to 35°C is due to the higher amylose content's causing the development of aggregated structures with increased viscosity. Compared to corn starch, Amaranth cruentus and *Amaranth*. hypochondriacus starches had higher swelling power, lower solubility, greater water uptake, lower susceptibility to a-amylase, higher amylograph viscosity, and much lower amylose content. High susceptibility of Amaranth hypochrondriacus and Amaranth caudatas starch granules to amylases was reported by (Tomita et al. 1981).

Amaranth Protein

Amaranth is among the highest protein grains in the world for its balanced composition of essential amino acids (Spore,1992).The Amaranth protein quality was higher than cereal proteins comparable to soy proteins, indicating that its as a food additive should have no adverse effect on nutritional quality. Amaranth grains contain about 15% of protein and 60% of starch. Its amino acid profile makes it an attractive protein source because of its high lysine content and it tends to be viewed as a protein that, if consumed along with other cereals, can provide a "balanced" protein source (Pedersen et al., 1987) As a consequence there has been an increasing interest in using amaranth flour in blends with wheat or maize.

Mixed flours of wheat and amaranth possess an ideal balance of amino acids, and the protein of such mixed flours has a biological value which is 2.5 times higher than that of maize flour (Guenault,1985) and mixing in proportion 30:70 has been found to raise protein quality based on casein(Bressani,1989) Ordinary maize meal supplemented with as little as 12.7% (by weight) of toasted amaranth flour provides a nutritionally superior source of protein that can satisfy a good portion of the protein requirement of young children, and provide approximately 70% of diet energy (Morales et al. 1988). A combination of rice and amaranth in a 1:1 ratio has been reported to approach the FAO/WHO protein specifications (Singhal and Kulkarni 1988). Protein content of A. hybridus seeds is high and it is rich in mineral elements particularly Mg. A. hybridus seeds can be suggested as an alternative to maintain and reinforce the immune system in humans and also used as cattle food (Dhellot *et al.*, 2006).

***Amaranth* Oil**

Amaranth grain consists of approximately 6 to 10% oil, found mostly within the germ which is generally higher than other cereals (Betschart *et al.* 1981, Lorenz and Hwang 1985, Garcia et al. 1987a). The lipid fraction of amaranth grain is predominantly an unsaturated oil (76%) particularly high in linoleic acid, which is necessary for human nutrition. In analyses conducted at the USDA Western Regional Research Center, amaranth oil was found to have 7% squalene, which is much higher than the amounts found in other common vegetable oils. Squalene, a high priced material, is traditionally extracted from shark and whale liver oil which contains 30-45% and used in cosmetics (Lyon and Becker 1987).

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 physical activity, edema of the legs towards the evening hours and feeling of intermission of heart function in most patients Diet with amaranth oil may help reduce blood pressure and could serve as an effective alternative to drug therapy in people with hypertension. Matirosyan et al, 2007 study also .showed that a combination of amaranth oil with a hypo sodium antiatherogenic diet is more effective to reduce the amount of blood cholesterol than just the hypo sodium anti atherogenic diet (Matirosyan *et al*, 2007). Amaranth oil is reported to contain high concentrations of tocotrienols, rare forms of vitamin E that inhibit key regulatory enzyme in cholesterol biosynthesis. Also, it has been found that amaranth oil contains larger amounts of isoprenoid squalene than other common vegetable oils (Becker 1989).

Squalene is a known obligatory biosynthetic precursor for all steroids, a powerful antioxidant and its content in the grain increases the nutritional importance of amaranth grain. Squalene increases the oxygen supply to the cells of the human body. It seems that this oxygen-carrying function plays a key role in lowering low-density lipoprotein blood cholesterol, enhancing the immune system and even preventing cancer. Squalene content in Amaranthus cruentus has been reported to be 0.43% of the total seed weight. In addition, squalene was also present at 0.73% in the seed of Amaranthus hypochondriacus and at 1.32% in the seed of Amaranthus pumilus (Becker, 1994., Marcone,2000).Anti nutrients, such as trypsin inhibitors and tannins, are at low levels that they do not present a nutritional hazard (Breene 1991; Budin et al. 1996). Amaranth suggests that it offers cholesterol-lowering effects. In an experiment conducted by Graj *etal*., (1997) with rats, a reduction of 37% and 33% of total cholesterol when the animals were fed diets with whole amaranth and defatted amaranth, respectively.

Vitamins and Minerals

Amaranth has high nutritional value due to its high content of essential nutrients like carotene, vitamin C, potassium, iron and calcium .Iron content of amaranth is five times more than wheat. It contains two times more calcium than milk. Amaranth has been rated considerably higher in minerals, such as calcium, iron, phosphorous and caretonoids than most vegetables. Thermal treatments including cooking and popping showed no effect on the content of most of the minerals. A reduction of the level of sodium and iron was observed due to cooking in both species, while popping caused a reduction only for the sodium content in A. caudatus. Cooking eliminated vitamin C in A. cruentus and reduced it to 8.0% of its initial amount in A. caudatus. The lowest reductions of vitamin C (38.6 and 30.4%) were observed for the popped seeds of A. caudatus and A. cruentus, respectively. The seeds germinated and dried at 30 ◦C showed the highest amount of ascorbic acid followed by seeds germinated and dried at 60 and 90 ◦C (Gamel *et al.*, 2006).

Cooking reduced the pyridoxine content by 51.0 and 49.0%, while popping reduced pyridoxine with 11.0 and 10.0% in A. caudatus and A. cruentus seeds, respectively (Gamel *et al.*, 2006).

Nutraceutical effects

Nutraceutical effects for this crop are probably associated with fiber, squalene, tocols, or the lectin biomarker called amaranthin (Rinderle *et al.*, 1989). The fibre content of Amaranth seeds is three times that of wheat, it also has a higher concentration of soluble fibre than many cereals, such as wheat, corn or oats. The association of ferulic acid, an alkali-

extractable phenolic acid is an insoluble fiber and non-starch polysaccharide in amaranth (Amaranthus caudatus L., Amaranthaceae was investigated by Mirko Bunzel *et al* (2005). Ferulate is a minor component of the cell wall that is bound to plant cell wall polymers, e.g., polysaccharides and lignin. Dimerization of polysaccharide-bound ferulates is a convenient mechanism to cross-link polysaccharides. Thus influencing the physicochemical properties of the plant cell wall and as a consequence the physiological effects of the dietary fiber.

Amaranth oil and squalene are used for oncological treatments, sclerosis, malfunction of the brain, immunodeficient states, skin, stomach and liver diseases, wounds, bedsores, and ulcers (Bogolyubov, 1999). Squalene, a powerful antioxidant used as a dietary supplement for diabetes and those suffering from hypertension and metabolic disorders (Teutonico and Knorr, 1985). Application of squalene in nutraceutical and pharmaceutical fields has been increasing progressively, so the demand for this substance is expected to increase continuously. This compound is now widely used as an important ingredient in skin cosmetics and as a lubricant for precision instruments (Sun *et al*, 1995).

Tocols have been characterized in amaranth seeds and include gamma and delta tocotrienols, the unsaturated forms of vitamin E have shown to affect cholesterol biosynthesis in humans by possessing antioxidant activity and are under scrutiny as hypocholesterolemic and antitumor agents. Amaranthus cruentus L. and A. hypochondriacus L.; which contain gamma and delta tocotrienol in addition to most common tocopherols and tocotrienols. (Lehman.,1994). Since it is a gluten-free food, amaranth seeds have been recommended for people with celiac disease (Kupper, 2005).

Amaranth paniculatus and Amaranth cruentus are good sources of flavanoids, especially for rutin, which are mostly produced in the stage of blossoming.

Conclusion

Amaranth grows vigorously in most climates and needs a minimum of water. Both the leaves, which taste like spinach and the seeds, contain a high concentration of lysine, an essential amino acid lacking in all of the world's main cereal crops. Addition of amaranth to other cereal flours improved protein quality without affecting energy utilization. Amaranth is also highly suitable for utilization in infant formulas. The seeds can be used for breads, pastries, or can be popped like corn. In addition to its high fiber, calcium and iron, amaranth also has two times more calcium than milk. When used in combination with wheat, corn or brown rice amaranth offers a complete protein as high in food value as fish, red meat or poultry. Cooked amaranth has a total digestibility of about 90%. Amaranth's unique nutty flavor makes it a welcome addition to many types of food products.

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