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Review Article

Application of pseudocereal (amaranth grains) in dairy and food products: A review

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Abstract

Amaranth (*Amaranthus* spp.) is a nutrient-dense pseudocereal that has gained significant importance for its potential applications in functional foods and dairy products. Rich in high-quality proteins, essential amino acids, unsaturated fatty acids, dietary fiber, minerals, and bioactive compounds such as squalene and polyphenols, amaranth offers both nutritional and health-promoting benefits. The unique composition of amaranth makes it suitable for addressing protein-energy malnutrition, gluten intolerance, and lifestyle-related disorders. In the food industry, amaranth grains and their processed forms (flour, starch, protein isolates, and popped grains) have been successfully incorporated into bakery products, extruded snacks, breakfast cereals, and beverages to improve their nutritional quality and functionality. In the dairy sector, amaranth is utilized for fortifying milk-based products, yogurts, ice creams, and several sweets, contributing to enhance protein content, textural properties, and functional attributes. Its antioxidant and cholesterol-lowering properties further broaden its scope in the development of health-oriented products. Despite these promising applications, challenges such as the presence of anti-nutritional factors, sensory acceptability, and optimization of processing techniques need to be addressed for large-scale commercial use. This review highlights the nutritional potential of amaranth grains, their technological applications in dairy and food systems, and future perspectives for their utilization as a functional ingredient in promoting sustainable and health-oriented product development.

Keywords: Compositions, Dairy products, Nutrition, Popping, Pseudocereals

Highlights

- Amaranth is a nutrient-rich pseudocereal with high-quality proteins, essential amino acids, and bioactive compounds
- It is gluten-free, making it suitable for special diets and functional food formulations
- Amaranth grains and derivatives enhance nutritional and functional properties of bakery, snack, and beverage products
- In dairy systems, amaranth is used to fortify milk, yogurt, ice cream, and infant formulations
- Exhibits antioxidant, cholesterol-lowering, and health-promoting effects
- Processing challenges include anti-nutritional factors and sensory acceptability

INTRODUCTION

The greatest threat to the survival of humanity is increasing gap between population growth and food supply. To bridge this gap, much attention has been centered on the exploitation and utilization of pseudo cereals. Due to its nutritional potential, phytochemical content and gluten-free nature, a considerable interest has been focused on its utilization. Pseudo cereals represent a growing niche sector in Europe, where the demand is on the increase annually.

Pseudocereals extensively consumed in Middle America during pre-hispanic times were dicotyledonous plant species, which were not closely related to each other or to the monocotyledonous true cereals. The name derived from their production of small grain like grains. Presently, the grain amaranth grain (Amaranthus spp *Amaranthaceae*), quinoa (*Chenopodium quinoa*, *Chenopodiaceae*), and buckwheat (*Fagopyrum esculentum*, *Polygonaceae*) are important pseudocereals that have persisted through centuries of civilization and have entered into the agricultural system of the countries where cereals are cultivated. Pseudocereals are being used in same way as cereals to a great extent (true cereals are grasses). The seeds of pseudocereals can be ground into flour and otherwise used as cereals.

Pseudocereals can be defined as fruits or seeds of non-grass species that are consumed in a similar way as cereals, having nutritive value very much competitive to conventional crop, in most cases even better

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(Das, 2016). Pseudocereals are good sources of high-quality protein, fiber, minerals and possess bioactive and health-promoting effects (Thakur & Kumar, 2019). These have no gluten content and therefore, have wide application in gluten- free products.

Amaranth grain

Amaranth, being one of the ancient crops (Amicarelli & Camaggio, 2012), consists about 70 species of the genus Amaranth which are found in tropical and subtropical regions of world, where 40 are native to America, 17 species are vegetables whereas, 3 are grains, and rest are weeds (Andreas et al., 2011). The cultivation of amaranth is low, and it is not even reported in FAO statistics on production of amaranth (Valcarcel-Yamani & Lannes, 2012). But its high nutritional content and adaptability to harsh environmental conditions has made it a gain of interest (Kamalet al., 2022 and Malik et al., 2023) and have received worldwide attention (Kumar et al., 2024).

The three species of *Amaranthus*, produced are *Amrnthus hypochondriacus* and *Amaranthus cruentus* originated in Mexico and Gautemala and *Amaranthus caudatus,* native to Peru and the Andean countries, commonly grown for their edible seeds. It was one of the major food crops of the Aztecs, and some have estimated amaranth was domesticated between 6,000 and 8,000 years ago. The Aztecs didn't just grow and eat amaranth; they also used the grain as part of their religious practices. This grain migrated to India from America and become an important part of our fasting ritual. The highest producers of amaranth grain are Mexico, Russia, China, India, Nepal, Argentina, Peru and Kenya.

Amaranthus, commonly known as *rajgiri, ramdana, kerai*, king seed in India, which is mainly cultivated in the Himalayas extending from Kashmir to Bhutan and also in high altitude regions of South India. The proximate compositions of amaranth grain is depicted in Table 1.

Nutritional and functional properties of amaranth: Amaranth has a higher nutritional value than some staple cereals and legumes as it contains high in calcium, iron, magnesium, phosphorus, and potassium. It's also the only grain to contain Vitamin C. It is known to be a very nutritious pseudocereal with exceptionally high protein content as compared to the true cereals (Malik et al., 2023). Difference in nutritional content of different species of amaranth is noticeable. This plant attributes large content of highly digestible complete protein with the presence of all essential amino acids in the seeds. Amaranth seeds also contain large amounts of gluten-free starch with a small grain diameter and fibre. They have a high fat content compared to staple cereal grains. Amaranth oil consists mainly of unsaturated fatty acids (oleic, linoleic and linolenic), essential for the human body (Skwary³o-Bednarz et al., 2020). The nutritional values of cooked, edible form of amaranth grain is mentioned in Table 2.

Table1. Proximate composition of Amaranth

Parameters	(g/100 g)*	(g/100 g)**
Protein	16.5	14.9
Fat	5.7	9.1
Total starch	61.4	Na
Dietary fibre	20.6	12.0
Ash	2.8	2.9

(Source * Alvarez–Jubete et al. 2009; ** Bonafaccia et al. 2003)

Table 2. Nutritional values of cooked, edible form of amaranth grain

Composition:	Amaranth grain, cooked
Component (per 100 g portion)	**Amount**
Water (g)	75
Energy (KJ)	429
Protein (g)	4
Fat (g)	2
Carbohydrates (g)	19
Fiber (g)	2
Sugars (g)	n/a
Iron (mg)	2.1
Manganese (mg)	0.85
Calcium (mg)	47
Magnesium (mg)	65
Phosphorus (mg)	148
Potassium (mg)	135
Zinc (mg)	0.9
Pantothenic acid (mg)	<0.1
Vit B6 (mg)	0.11
Folate (µg)	22

Source: http://en.m.wikipedia.org

Unlike most conventional grains such as rice, wheat, and corn which are low in lysine, Amaranth makes an attractive source of protein, and it can provide a ''balanced'' protein content. The developing countries are also giving the Amaranth species great attention as a means to overcome protein malnutrition. It is a reasonably well-balanced food with functional properties that have shown to provide medicinalbenefit (Malik et al., 2023).

The health benefits attributed include decreasing of plasma, cholesterol levels, reducing blood glucose levels, stimulating the immune system, exerting an antitumor activity and improving conditions of hypertension and anemia. In addition, it has been reported to have anti- allergic and antioxidant activities. The Amaranth is gluten-free and hence easy to digest and because of its ease of digestion, it has traditionally been given to those recovering from illness or fasting period.

Carbohydrates: Amaranth seeds contain 65 to 75% starch, 4 to 5% dietary fibers, and non-starch polysaccharides. Sucrose is the major sugar, followed by raffinose, whereas inositol, stachyose, and maltose occur in small amounts. Starch, tightly packed in grain structure, mainly composed of amylopectin (97.9%). The digestion time of amaranth starch (3h) by amylase is less than that of maize starch (Skwaryło-Bednarz et al., 2020). As compared to the starches of maize and wheat, Amaranth's starch have a higher swelling power, lower solubility, greater uptake and lower amylose content.

Proteins: Amaranth does not contain gluten and is therefore suitable for diets of persons with celiac disease. According to the classification of Osborne, the amaranth protein consists of about 40 % albumins, about 20% globulins, 2-3% prolamins, and 25-30% glutelins (Singh et al., 2024). So albumins and globulins are predominant, while prolamins are only to be found in small amounts. The high content of Arginine and Histidine, which are essential amino acids for infants, also makes amaranth valuable for infant nutrition. 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 (Drzewiecki et al., 2003). Amaranth has high soluble fiber content 4.2%, and a reported protein concentration between either 12.5% or 17.6% (Venskutonis & Kraujalis, 2013), or between 16.09% and 18.19% (Robert, 2018). Its Methionine contents is around 15.8 mg/g total protein, whereas its lysine levels are about 55.8 mg/g total protein. The high lysine and methionine concentrations support the high nutritional quality of the grain, especially when compared to other grains in which those amino acids are present at limited levels (Bressani, 2018), the amaranth grain is considered a good source of insoluble fiber also.

Vitamins and Minerals: Amaranth has also been recognized because of its high vitamin and mineral contents, such as riboflavin, niacin, ascorbic acid, calcium, and magnesium contents (Sarker et al., 2020) With regards to vitamin B content, amaranth is a good source of riboflavin. In addition, amaranth are excellent sources of vitamin E. Total vitamin E content in amaranth, quinoa and buck wheat seeds has been reported to be 5.7, 8.7 and 5.5 mg/100 g dry weight basis, respectively, (Bruni et al.,2001). In particular, the high calcium content in amaranth seeds is of special relevance for celiac subjects due to the well-known prevalence of osteopenia and osteoporosis among newly diagnosed celiac patients.

Fat: Amaranth, quinoa and buckwheat lipids are characterized by a high degree of unsaturation, which is desirable from a nutritional point of view (Valencia-Chamorro et al., 2017). Linoleic acid is the most abundant fatty acid (50% of the total fatty acids in amaranth and quinoa, and approximately 35% in buckwheat) followed by oleic acid (35% in buckwheat and 25% in amaranth and quinoa) and palmitic acid (Alvarez-Jubete et al., 2009). A high content of linolenic acid is beneficial, that an increased intake of fatty acids reduces biological markers associated with many degenerative diseases such as cardiovascular disease, cancer, osteoporosis, and inflammatory and autoimmune diseases (Simopoulos, 2016).

The causes of anemia may be due to a number of situations, including chronic infections; hereditary blood problems; or the lack of one or more essential nutrients necessary for the formation of haemoglobin, such as iron, folic acid, B_{12}, B_6 and C vitamins, and proteins. Iron deficiency anaemia is the most common kind of anaemia (Longo & Camaschella, 2015) and amaranth grain may be used as an interventional carrier to fight the deficiency. So, amaranth acts as an anti-anaemic effect.

Minerals: Seed of grain amaranth is a rich source of iron (72 to 174 mg kg-1), calcium (1,300 to 2,850 mg kg-1), sodium (160 to 480 mg kg-1), magnesium (2,300 to 3,360 mg kg-1) and zinc (36.2 to 40 mg kg-1) as well as vitamin riboflavin (0.19 to 0.23 mg 100 g-1 of flour) ascorbic acid (4.5 mg 100 g-1), (Becker et al.,1981).

Technological realization of Popping

Principally two different processes exist to pop the seeds of amaranth. Traditionally amaranth was, and still today, popped by direct heat contact on a hot surface. To proceed this way previously cleaned amaranth seeds are laid on a hotplate at about 190°C and after 15 - 30 s expansion occurs. The popped seeds should be removed from the hot surface as rapidly as possible, because they burn easily and reduce the quality of the product. The low surface to grain heat transfer makes the traditional popping method very slow and highly inefficient. Therefore, this method has been modified. For commercial use, a vibrating plate made from steel, which is installed in an angle of 10-15°, is heated from several points below. The popped seeds fall automatically into a container where they are cooled (Brito & Tovar, 1995).

In addition to this traditional process, an improved process was developed in which the amaranth seeds are popped by hot air (Zapotoczny et al., 2006). This process is called a "fluidized bed system" because of the construction of the equipment. By means of moving hot air (220 - 225°C) of a particular velo city the amaranth seeds, which are fed in at another point, are lifted and popped by the heat. As the popped seeds have a lower specific weight they are carried out of the column by the moving air and are caught in a separate container. There is no additional equipment is required for separation of popped from unpopped grains. It only takes 2 - 4 s until the seeds are expanded. 75-80% of the amaranth seeds were popped using this method and the rest were roasted (Tovar, 2018). In comparison, the yield with the tradition al method was only around 65 %. One of the advantages of this process compared to the traditional one is that the seeds are not exposed to heat for too long and therefore over heating or burning can be prevented. The operating conditions in a fluidized bed such as popping temperature, hot air velocity, and feed rate can be easily controlled, making scaling-up of the operation possible. Furthermore, equipment can be designed and built to meet hygienic requirements for preparing food for human consumption (Brito & Tovar, 1995). Additionally, the same equipment can be used for cleaning the seeds, when the seeds are run through the machine at room temperature. Due to the short popping duration of this "hot-air popper" the losses of nutrients can be considerably minimized developed an additional popping method, which involves a "pneumatic conveying flash dryer", which works in a similar way to the fluidized bed system. (Evason & Davies 1991) patented an apparatus in which amaranth seeds are popped with hot air (Hubbard & Guanella, 1991).

Physico-chemical changes during Popping

During popping a partial "gelatinization" of the starch granules occurs before the water transits from the fluid phase to the vapor phase. This process is very rapid and only takes 3 - 6 sec depending on the method. By means of steam the starch is cooked within the perisperm, which expands and breaks the seed coat. Additionally, the storage protein is denatured by the steam, while the compact protein of the germ probably contributes to the structure barrier, which makes itpossible that within the seed a high pressure can develop. The perisperm expands into a soap bubble-like form, where depending on the method 2-4 such soap bubbles are formed. The seed coat only hangs loose at the perisperm and has a light brown color, while the perisperm appears bright white. The embryo remains intact in most of the popped seeds. The volume of the popped seeds increases by four- to eight-fold and the specific weight decreases correspondingly. The process is influenced by exposure time to the heat treatment, by the popping process, the amaranth variety, and the moisture content of the seed. Depending on how those parameters are changed, the seed is popped, toasted, or roasted. Amaranth is toasted when the seed is exposed for 60 - 90 s at about 150°C, usually on a hot surface, and no popping occurs. Roasting occurs when the seed is subjected to very hot temperatures (above 150p C) for a longer period, where partial popping can happen prior to roasting. During this process, the seeds can easily be over-roasted or burned. Variables like moisture content, species, variety, and genotype are critical in order to obtain a satisfactory yield. The moisture content of the amaranth seeds and achieved the highest yield at around 12-14% moisture (Evason & Davies, 1991).

Solanki et al. (2018) studied the popping characteristics of amaranth grain and observed that the grains can be popped through intense, short and dry heat and stated that popped seeds are very soft in texture and can be incorporated for new recipe formulations or ready to eat products. Beniwal et al. (2019) reported that processing of grain resulted in reduction of saponin and tannin content of amaranth and quinoa grain and decreased significantly the anti-nutritional component. Germination was the best treatment among the processing treatments in improving nutritional value in term of protein content.

Nutritional changes during Popping

It is evident from various standards intense; dry heat decreases the nutritional value of many cereals and other foods. The pro989teins react with reducing sugars to form Maillard products. Primarily, the essential amino acid lysine reacts to a high degree with reducing sugars. According to Zapotoczny et al. (2006), lysine, arginine, and cystine were partially damaged in amaranth during popping. Aspartic acid, glutamine, alanine, and phenylalanine were partially racemized, as occurs in the roasted seeds. Tryptophan and threonine showed no losses.

Lysine seems to be the limiting amino acid in popped seeds, followed by the sulfur-containing amino acids. Evason & Davies (1991), in contrast, did not find a loss of lysine in their popping method. The digestibility of popped amaranth is higher than in the raw seed, but lower than in wet cooked seed. This is probably due to unfolding of the proteins (Bressani, 2018).

During popping the seed coat is partially lost, may be due to partial losses of dietary fiber, minerals, and perhaps also water-soluble vitamins (Tovar, 2018). Changes in the amaranth oil may also take place during popping. The color becomes darker, and the proportion of free fatty acids and the viscosity increase, which is indicative of polymerisation (Becker, 1981). The unsaturation of the oil decreased from 75.5 to 62.3 % (Singhal & Kulkarni, 1988). The maximum effect was on linoleic acid, the quantity of which decreased sharply from 46.8 to 27.0%. Squalene increased to 15.5% due to popping. Through improvement of the popping process the losses of nutrients can probably be further reduced (Brito & Tovar, 1995).

Effect of processing on anti nutritional factors

Antinutrients, commonly occur in plant-based food is a substance which acts antagonistically toward one or multiple nutrients, reducing its bioavailability. Dry and wet heat processing techniques have impact on the nutrient and anti-nutrient contents of amaranth grain. The dry heating processes include roasting and popping while the wet heating techniques consist of boiling whole grains and slurries. Toxic compounds in amaranth, including phenolic compounds-saponins, tannins, phytic acid, oxalates, protease inhibitors, nitrates, polyphenols, and phytohemagglutinins.

Popping and germination of amaranth grains decreased the amounts of trypsin inhibitors and saponins, whereas lectins decreased significantly, especially after germination (Valadez-Vega et al., 2022). Processing treatments such as soaking and germination is a simple techniques to improve the nutritional and sensory characteristics of pseudocereals. These processing treatments increased the nutritional components such as proteins, phenolic components, and antioxidant activity, significantly. Surged lipolytic activity during germination caused reduction in fat content of germinated grains. The crude protein, crude fiber, antioxidant activity, and phenolic compounds increased in germinated pseudocereals. Leaching of tannins during soaking and its further degradation during germination with significant shoot in the activity of enzyme phytase resulted in the reduction of anti-nutritional components, thereby increasing mineral availability (Thakur et al., 2021).

Extrusion technology is used for semi-dry cooking of cereals for snack foods, breakfast cereals, baby foods, and pasta (Offiah et al., 2019). Lohani and Muthukumarappan (2017) found that technological properties, such as antioxidant activity and total phenolic content, water solubility index, and crispness, increased while hardness and water absorption decreased after extrusion cooking of pseudocereals. The extrusion also increased starch digestibility and dietary fiber content of grains. Lactic acid fermentation of pseudocereals to obtain sourdough is a powerful way to increase vitamin B content. *Levilactobacillus brevis* and *Propionibacterium freudenreichii* strains were used to increase vitamin B12 in buckwheat, sorghum, amaranth, and quinoa. *P. freudenreichii* enhanced the vitamin production, while *L. brevis* provided microbial safety (Xie et al., 2021).

Cereal and Pseudocereal based product

Rava Burfi: Rava burfi is a heat desiccated sweetmeat prepared from a mixture of milk solids, rava (semolina) and sugar and sometimes garnished with nuts. Shrivas et al. (2015) developed a method of manufacture for Rava burfi. Range of process parameters, like level of Khoa (140 to 160 g/100 g rawa), sugar syrup concentration (75 to 80°Brix) and liquid glucose (10 to 20 % replacement of sucrose), were studied and optimum values determined using Response Surface Methodology (RSM) with central composite rotatable design (CCRD). The optimized process developed with 157.76 g khoa (per 100 g rawa), 79.36 °Brix sugar syrup concentration and 16.20 liquid glucose as % replacement of sucrose produced the most acceptable product.

Kalmegh (2020) prepared burfi with rajagira (*Amaranthus caudatus*). Burfi was prepared with different combinations of khoa and popped rajgira as 100:00, 95:5, 90:10, 85:15, 80:20 and 75:25, respectively. Popped rajgira was mixed with khoa at dough stage and then, cane sugar was added, mixed and heated till solidification. Burfi prepared with 10% rajgira was found acceptable in all sensory attributes. Study revealed that with an increase in the concentration of rajgira, protein and carbohydrate content of burfi increased while fat decreased. Nganthoibi (2021) prepared besan burfi by incorporating 5, 10, 15, 20 & 50% percent of popped amaranth grain flour. Besan mixed with popped amaranth grain flour heated with ghee in a pan till the colour changes. Then, powdered sugar, almond and cardamom are added to the heated mixture and cooled. Besan burfi with 5% incorporation of 5% percent of popped amaranth grain flour obtained highest sensory scores.

Halvasan: Halvasanis a burfi-like product supplemented with wheat (cereal), maida and nutmeg. Chaudhary (2011) standardized a method for manufacture of halwasan. The pasteurized full- cream milk (Fat 6.0%, SNF 9.0%) used for manufacturing Halvasan was procured from Vidya Dairy, Anand. A stainless-steel jacketed steam kettle was used in preparation of Halvasan from standardized milk (Fat/SNF=0.66). After transferring the milk to S.S kettle, the heating and agitation was continued till the milk gets heated. At this stage, weighed amount of fada (@ 5% of milk) and maida (@ 2.5 % of Milk) paste were added and kept that whole mass undisturbed for at least 2 hours until the milk was coagulated, with separation of little watery part, and it was converted into coagulated mass. There after weighed amount of sugar (@17 % of milk) was added. Further heating with agitation was started for half an hour. Evaporation of extra moisture and development of colour and flavor in final product. The gross average chemical composition of market samples of Halvasan by Patel et al. (2010) had moisture-16%, fat-7.61%, protein-10.08%, sucrose-26.07%, lactose-13.47% and ash-1.31%. According to them physico- chemical quality attributes of market Halvasan having Acidity - 0.314 %L.A., FFA - 1.35 % Oleic Acid, HMF- 395.78 μ moles/100 g, pH- 5.82, Soluble nitrogen- 0.93 %, TBA - 0.27 O.D. at 532 nm and Water Activity -0.78.

Dodaburfi: Dodaburfi simply called as "doda" or "dhoda" is a popular sweet in northern India, especially states like Delhi and Punjab. It has dark brown colour, granular body, thick consistency, chewy mouth-feel and possess a pleasant aroma. The product has slightly longer shelf-life than other milk-based sweets. It is one of rare sweet traditionally made using a combination of cereal flour and milk solids and hence provides most of the nutrients, specially the fiber and micronutrients. At present, "doda" is manufactured by sweet-makers, at home and by Haryana Milk Marketing Federation Ltd. on commercial scale but the product do not have any optimized standard recipe, which leads to wide variation in quality characteristics. Dodaburfi is similar to kalak and milk cake in appearance and certain other characteristics. Kakkar (2016) developed Burfi from coriander (*Coriandrum sativum*) and buckwheat flour (*Fagopyrum esculentum*) in a ratio 60: 40. Roasted coriander powder mixed with fried buckwheat flour in the mentioned ration with addition of hot sugar syrup (78 brix). Then, the mixture was cooled and cut into desired shape. Coriander: buck wheat (60:40) Burfi had 13.53% moisture, 8.60% protein, 12.69% crude fat, 14.39% crude fiber, 1.11% ash, 63.21% carbohydrates and 5.75 mg/100 g iron.

Ragi Burfi: A standardized method of manufacture of *ragiburfi* was developed from this study. The optimized formulation consisted of addition of @ *khoa*107.68 g/100 g *ragi*, use of 76.48 °Brix sugar syrup concentration, and 31.31 g *ghee*/100 g *ragi*. From amongst different flavours screened for manufacturing of *ragiburfi,* it was found out that chocolate 1.25% in combination with vanilla 1 mL/kg was most suitable. *Ragiburfi* could be a "good source of calcium, iron and dietary fibre" providing 14.07, 13.93, and 10.11 per cent DV respectively. (Narwade , 2018). Mohod et al. (2020) prepared burfi with finger millet. Finger millet flour (10 to 25 %), khoa and sugar (30 % of weight of khoa) were added and heated gently to obtain the desired consistency. Study concluded with use of finger millet @15 per cent of khoa with @ 30 per cent sugar by the weight of khoa to get best quality of burfi.

Khubahi: The plants of *Scirpus articulatus* yield black colored seeds that are consumed in the form of sweets in the districts of Bihar. The seeds are popped by roasting them on sand, and their pops are processed into granular sweets after passing them in hot concentrated sugar solutions. It provides livelihood to the poor and backward classes of Bihar. Many variety and tasty sweets of khubahi are also prepared by mixing khoa (condensed milk) and are sold at a commensurate price. Khubahi pops are the only food item prescribed to the patients of smallpox because of their easy digestion without involving the movement of jaws. The patients suffering from this disease find it difficult to articulate their mouth parts with sores inside

The shift in consumption trend to pseudo cereals is being observed because of their nutritional importance, It has been utilized in developing gluten-free products like bread, pasta, confectionery products, etc (Alvarez-Jubete et al., 2009).

Bakery products: Gambus et al. (2001) investigated the possibility of amaranth to be used in the production of gluten-free bread to improve the nutritional composition (increased proteins, fiber, and mineral content) of final product.

Iron fortified gluten-free bread based on amaranth was formulated by Rai and Chopra (2018). Popped or extruded amaranth used to produce granola bars and museli with good sensory characteristics (Pandey & Rao, 2016; Schoenlechner et al., 2010).

Gluten-free biscuits with higher protein content than the traditional biscuits have been produced by using whole grain amaranth flour (Tosi et al., 1996) and also amaranth flour is recommended to be used in development of gluten–free crackers by Castro-Giraldez et al. (2012).

Dairy Products: Patel (2022) developed a flavoured milk combining the nutrient properties of milk, amaranth and dates. It was prepared from milk containing fat at 3.0% fat with addition of 0.15% sodium citrate, which prevented coagulation during sterilization. The levels of roasted amaranth flour, date extract and sugar for preparation of flavoured milk were optimized using RSM with CCRD using three independent variables. The suggested solution from RSM analysis for ADFM was: level of roasted amaranth flour: 1.61 % w/w of milk, level of date extract: 5.16% w/w of milk and sugar: 6.0% w/w of milk.

Nakov et al. (2025) studied the chemical, microbiological, and sensory characteristics of yogurt enriched with amaranth seeds, stored at a temperature range of 5±1°C for 21 days. Statistically significant results (pd”0.05) showed an increase in acidity with increase in storage time at 5 & 10% incorporation of amaranth into the yogurt. The inclusion of amaranth seeds in yogurt resulted in the increase in protein content of the final product.

Shinde et al. (2020) studied the suitable form of amaranth grain flour for the development of composite fermented milk drink. Studies revealed that the fermented milk drink prepared with roasted amaranth grain flour was highly acceptable than sprouted and non-roasted one.

Conclusion

Amaranth grains are a nutrient-dense pseudocereal with excellent potential for use in dairy and food products. Their high-quality proteins, bioactive compounds, and gluten-free nature make them suitable for functional and health-oriented formulations. Incorporation into bakery products, beverages, milk-based foods, and infant formulations has shown improvements in nutritional value, texture, and health benefits such as antioxidant and cholesterol-lowering effects. Despite these advantages, challenges like anti-nutritional factors, processing limitations, and sensory acceptability remain. Addressing these gaps through innovative technologies and consumer-focused research will support wider adoption of amaranth as a sustainable ingredient in future food systems.

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