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A Comprehensive Review Of Amaranth Grain: A Promising Nutrient In The Fight Against Chronic Diseases

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Abstract-
This research aims to examine the nutritional and therapeutic potential of amaranth (Amaranthus spp.), a grain of historical significance that has gained recognition for its exceptional nutritional value. The historical significance of amaranth as a staple in numerous cultures is examined, highlighting its abundance of important minerals and micronutrients. This particular food product is notable for its moderate protein composition and elevated concentrations of essential amino acids such as lysine and methionine. Furthermore, this study explores the pharmacological qualities of Amaranthus spinosus Linn., which
encompass diuretic, febrifuge, and anti-inflammatory activities. This study investigates the effects of amaranth on cholesterol levels, blood glucose levels, and its antioxidant qualities. The findings provide data indicating the potential of amaranth in mitigating oxidative stress and chronic diseases. Moreover, the highlighted aspect of amaranth is its anti-hypertensive
capabilities, which are ascribed to the presence of bioactive peptides. The review highlights the necessity for additional research in order to comprehensively comprehend the processes via which it operates. Furthermore, it advises exercising prudence when
consuming it, particularly for persons afflicted with diabetes, owing to its impact on glycemic index. In general, amaranth exhibits potential as a viable contender for the promotion of health and the prevention of disease.

Keywords: Amaranthus spinous Linn, Antihypertensive, Bioactive compounds, Glycaemic index

1. INTRODUCTION

Amaranth (Amaranthus spp.), a plant related to spinach, was a staple food for the Inca, Maya, and Aztec cultures. This ancient grain, a staple in several sections of the world's diet, has only recently achieved favor as a health food. This particular food item is considered to be a notable dietary source of various essential nutrients, including fiber, protein manganese, magnesium, phosphorus, and iron, among other significant micronutrients. As to the professional opinion of nutritionist Lovneet Batra, amaranth might be considered an extraordinary superfood that is currently underappreciated. The grain in question is an old staple that has been utilized in India for a considerable period of time. It has garnered the monikers of "Ramdana" (the grain of God) and "Rajgira" (the grain of kings). The taste profile of this food item is characterized by a subtle and distinct nutty essence. Since these pseudocereals are more nutritional and mineral dense, they are gradually replacing wheat flour in baked goods. Research is currently being conducted to explore alternatives to refined wheat flour in baking.

This is due to the deficiencies in protein, particularly lysine and threonine, as well as the reduced fiber content found in bread made from refined flour compared to whole flour bread. The aim of this research is to identify and incorporate alternative food ingredients that are rich in proteins and nutrients, with the ultimate goal of improving the overall quality of food products. The objective is to develop safe, healthy, and nutritious food options (Dewettinck et al., 2008). Amaranth, when utilized as a substitute for conventional grains in bakery products, exhibits a notable enrichment of dietary fiber, amino acids, and bioactive compounds derived from whole flours or the complete grain of cereal/pseudocereal. These constituents have been found to possess preventive properties against diseases linked to the heart disease risk factors such as cardiovascular diseases, arteriosclerosis, and colon cancer (Motta et al., 2019; Salas-Salvadó, Bulló, Pérez-Heras, & Ros, 2006).

An attempt was undertaken to reevaluate the significance of amaranth grain by emphasizing its capacity to modulate metabolism and impede or slow down pathological mechanisms in laboratory settings, living organisms, and human subjects.

Approximately 60 distinct species of amaranth exist, although not all of them are commonly included in everyday dietary choices. When picked and utilized early, the leaves of Amaranthus blitus, Amaranthus tricolor, Amaranthus cruentus, Amaranthus dubius, Amaranthus edulis, and Amaranthus hypochondriacs can be added to salads and soups. Grains from Amaranthus caudatus, Amaranthus hypochodriacus, Amaranthus cruentus, Amaranthus hybridus, and Amaranthus mantegazzianus are used in baking, while those from Amaranthus retroflexus, Amaranthus. viridis, and Amaranthus. spinosus should not be fed to humans or livestock.

There are similarities between this grain and a cereal and a leguminous seed, both in terms of its botanical origins and its nutritional profile. Protein and amino acid levels are intermediate between that of a grain and a bean, suggesting that it may be best thought of as a sort of "natural rice-bean mashup" (Amaya-Farfan et al., 2005). Amaranth contains a high concentration of soluble fiber (4.2%; Early and Early 1987) and a protein level of either 12.5%-17% (Teutonico and Knorr, 1985) or 16.09%-18.19% (Becker et al., 1981). (USDA, Release 24, 2010) Show that it has roughly 15.8 milligrams of ethionine and about 55.8 milligrams of lysine per gram of total protein. The grain's high nutritional quality can be attributed, in part, to the high concentrations of the amino acids lysine and methionine that it contains (Bressani 1989; Teutonico and Knorr 1985). This is especially true when the grain is contrasted with other grains, in which these amino acids are found in lower concentrations. Kadoshnikov et al. (2008) found that throughout the ontogenetic development of amaranth, the relative amounts of globulins and albumins are decreased, while the levels of glutelins and gliadins are enhanced. This occurs despite the fact that this pseudocereal shares the same classes of storage proteins as other grains. However, in comparison to the high amounts reported in wheat and other cereals, these authors found that amaranth contained a modest content of storage proteins (42% of the total). New medicinal compounds have largely been discovered through the study of plants. Metformin was found as a result of research conducted on Galega officinalis, a plant that is used for medical purposes (Aiman 1970). Plant-based treatments have recently received more attention than they once did (Ratnakar and Murthy 1996; Puri and Mohapatra 1997). There is a glabrous plant called Amaranthus spinosus (Amaranthaceae) that grows in the subtropical and tropical parts of India. According to Kirtikar and Basu (1993), the root of this plant has diuretic and febrifuge properties. Anti-malarial (Hilou, Nacoulma, and Guiguemde 2006), anti-diarrheal (Sawangjaroen and Sawangjaroen 2005), anti-hyperglycemic, antihyperlipidemic, spermatogenic (Sangameswaran and Jayakar 2008), and anti-inflammatory (Sangameswaran et al. 2008) activities have all been reported for this plant's extract. Additionally, it promotes the growth of T-lymphocytes (Lin, Chiang, and Lin, 2005). The plant used for this project is readily available in the Salem district and has long been utilized by locals to cure diabetes. Commonly called "bayam pasir," or Amaranthus viridis L. (A. viridis), this plant is a member of the Amaranthaceae family. In most tropical regions, you can find this glabrous, branching herb [7]. In India and Nepal, A. viridis has long been used as a pain reliever during labor and as an antipyretic [8]. In addition to these conventional uses, it is also used as an analgesic, antiulcer, antirheumatic, antileprotic, and antiemetic agent [9]. It is also used for the treatment of respiratory issues, asthma, eczema, psoriasis, and even eye ailments.

The Amaranthus spinosus Linn. the plant (also known as "Spiny amaranth," "Prickly amaranth," or "Spiny pigweed") is widely distributed throughout India and other parts of the world for its medical use. Invasive species of this plant are a widespread problem in rice fields (4). This plant has a long history of usage in Ayurveda (5), the traditional Indian system of medicine, where it has been employed in the management of diabetes (Tewari et.al. 2017), jaundice , and other conditions. Anti-inflammatory (7 studies), anti-diabetic (8 studies), anti-diarrheal (9 studies), anti-bacterial (10 studies), anti-microbial (11 studies), and anti-malarial (12 research) activities have all been found in this plant. In light of this, the scientific community is very interested in this plant's potential therapeutic uses. While specific plant components, such the leaves, have been studied for their phytochemical qualities in the past, the plant as a whole remains mostly mysterious to the scientific community, and very few attempts have been made to extract medicinal medications from it. Pharmaceutical drugs are typically made by isolating a useful phytocomponent from a plant. However, because we wanted to make a crude extract of a herbal medicine, we counted how many of the target secondary metabolites were present in the plant's various parts (leaves, root, stem, and flowers). Typically, cancer patients undergo some combination of surgery, chemo medicines, and radiation therapy. In addition to killing cancer cells, radiation and chemotherapy both induce cell stress, which in turn increases the production of harmful free radicals like reactive oxygen species (ROS) that react with different parts of the cell, causing severe oxidative damage to everything from the phospholipid bilayer to amino acids to DNA . In addition, the activity of anti-cancer medications inhibits the activity of physiological antioxidant enzymes such as superoxide dismutase. Therefore, it becomes essential to supplement the current therapies with an external antioxidant dosage in order to prevent the unwanted effects on healthy somatic cells. Secondary metabolites are organic molecules that are predominantly produced by plants as metabolic waste. Since they have useful pharmacological and biological qualities, they are put to use in medicine (Winck et al. 2015).

2. NUTRITIONAL AND CHEMICAL COMPOSITION

Twenty accessions of Amaranth (Amaranthus L.) were studied by Nathan Aliel Kachiguma (2015), and the results showed that the moisture content ranged from 10.69 to 12.22%, while the ash content varied from 4.4 to 8.7%. The samples were collected from a variety of agro-ecological zones. The grain had calcium (77.3– 1004.6 mg/100g), iron (3.61–22.51 mg/100g), magnesium (44.3–97.38 mg/100g), potassium (267.8– 473.6 mg/100g), and zinc (0.53–1.20 mg/100g), according to elemental analysis. Crude protein varied from 13.37 to 23.27%, ash from 14.08 to 19.95%, and vitamin c from 30.3 to 117.79 mg/100 g, with mean mineral leaf analyses in mg/100 g ranging from 14.84 to 31.17 for iron, 1.03 to 3.46 for zinc, 1512 to 2381 for calcium, 1320 to 1677 for potassium, and 383.4 to 513.9 for magnesium; these differences were highly significant (p 0.001). In order to evaluate the plant's many uses, the nutritional and chemical value of Amaranthus hybridus was analyzed using conventional techniques. The leaves had a calorific value of 268.92 Kcal/100 g, and its Proximate analysis revealed the following percentages: moisture content, ash content, crude protein, crude fat, crude fiber, and carbohydrate. According to elemental analysis, the leaves have 7.43 mg of sodium, 54.20 mg of potassium, 44.15 mg of calcium, 231.12 mg of magnesium, 13.58 mg of iron, 3.80 mg of zinc, and 34.91 mg of phosphorus per 100 grams dry weight (DW). -carotene (3.29 mg/100 g (DW), thiamine (2.75 mg/100 g (DW), riboflavin (4.24 mg/100 g (DW), niacin (1.54 mg/100 g (DW), pyridoxine (2.33 mg/100 g (DW), ascorbic acids (25.4 mg/100 g (DW), and -tocopherol (0.50 mg/100 g (DW)). A total of 17 different amino acids were identified: isoleucine, leucine, lysine, methionine, cysteine, phenylalanine, tyrosine, threonine, valine, alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, proline, and serine. It was reported that...(IE Akubugwo et al., 2007).

3. PHYTOCHEMICAL ANALYSIS

Ishir Sharma et al. 2023 screened plants for their phytochemical content using a variety of solvents. Quantitative analyses of alkaloids, saponins, flavonoids, polyphenols, and tannins were performed. Chemical assays based on colorimetry were used to determine the total concentration of secondary metabolites in each solvent extraction as part of the phytochemical screening of the AS plant extracts. Additionally, quantitative analysis was performed, which determined the concentration of secondary metabolites.

This formulation's other pharmacological actions, such as anticancer, antibacterial, and antifungal, can be explored thanks to the breadth of information provided by phytochemical analysis. This will allow for the evaluation of other qualities that could be useful in the treatment of many diseases and conditions, including cancer.

Solvent	Sample	Saponin test	Polyphenol test	Flavonoid test	Alkaloid test	Tanin test
Water Ext	Root	+++	+	+	++	+
	Inflorescence	+++	++	+	++	-
	Stem	+++	+	+	++	-
	Leaf	+++	+++	++	+++	-
Methanol Ext	Root	+++	+	-	-	-
	Inflorescence	+++	++	-	++	+
	Stem	+++	+	-	-	-
	Leaf	+++	+++	-	+++	-
Ethanol Ext	Root	+	-	+	-	-
	Inflorescence	+	+	-	++	+
	Stem	+	+	+	-	-
	Leaf	+	-	-	++	+
Chloroform Ext	Root	-	-	-	-	-
	Inflorescence	+	+	-	++	+
	Stem	-	-	-	++	+
	Leaf	-	-	-	-	-
Acetone Ext	Root	-	-	+	-	-
	Inflorescence	-	-	+++	-	-
	Stem	+	-	+	-	-
	Leaf	-	-	+	++	+

Table 1 shows that the qualitative analysis was tabulated by using the notation +++, ++, + for the presence of phytochemicals and – for the lack of phytochemicals. The quantitative ranges of concentration were tabulated by using the notation that follows. The rating scale for concentrations is as follows: a rating of "+++" corresponds to concentrations ranging from 1001 to 2000 µg/ml, a rating of "++" corresponds to concentrations ranging from 501 to 1000 µg/ml, and a rating of "+" corresponds to concentrations ranging from 0 to 500 µg/ml.

4. EVIDENCE OF HEALTH BENEFITS

4.1 EFFECTS ON CHOLESTEROL LEVELS

One of amaranth's most frequently mentioned skills is the adjustment of serum cholesterol levels, and several explanations have been presented to explain this effect.Researchers Danz and Lupton (1992) found that when rats were fed amaranth, the results were comparable to those seen with a soluble fiber's influence on serum cholesterol levels; however, the fiber behaved more like a poorly fermentable one in the colon. In a rat model, Sarojni G. and colleagues (1993) demonstrated that a diet containing amaranth had a hypocholesterolemia effect that resulted in a reduction of total cholesterol by a factor of fifty in comparison to a control diet containing casein. These researchers speculated that the presence of unsaturated fatty acids in amaranth could have been responsible for the observed effect.

According to research done by Danz and Lupton (1992), the consumption of amaranth by rats resulted in a reduction in cholesterol levels in the blood serum. This impact was comparable to that of a soluble fibre, but it also behaved in the colon like a poorly fermentable fibre would. Conversely, Nirmala GI et al. (1993) used a rat model to demonstrate that adding amaranth to a meal decreased total cholesterol by 50% when compared to a control diet containing casein. It was speculated by those authors that the unsaturated fatty acid content of amaranth may have contributed to the impact being seen.

Qureshi et al. (1996) conducted a study to examine the impact of incorporating amaranth into the diet for a duration of 6 weeks on cholesterol production in chickens. Amaranth-fed groups showed significant reductions in total and LDL cholesterol, although high-density lipoprotein-C (HDL-c) concentrations were unaffected. Cholesterol 7 alpha-hydroxylase enzyme activity was 10% to 18% greater and HMGCoA reductase activity in the liver was 9% lower in the experimental group compared to the control group. Cholesterol levels were found to be reduced thanks to the presence of powerful inhibitors of cholesterol synthesis, which were found to be present in amaranth in addition to the tocotrienols and squalene previously thought to be responsible.

Rats were fed a semi-purified diet containing 1% cholesterol for 4 weeks, and either amaranth grain or amaranth oil, which were substituted in the experimental groups, was given in the control groups. Heo HJ and colleagues (2004) reported some interesting findings on the effects of amaranth grain, oil, and squalene in this experiment. One of the experimental groups was additionally treated with squalene. Both the amaranth grain and the amaranth oil were able to lower the total cholesterol levels in both the blood and the liver, as well as the concentrations of triacylglycerol. Both bile acid and faecal cholesterol were elevated in the amaranth oil group, but only bile acid was increased in the amaranth group. In yet another trial, rats were given either a food high in cholesterol and salt (serving as a control), a diet high in amaranth squalene, or a diet high in shark squalene over a period of seven days. One notable finding of this study was the observed hypolipidemic effect of amaranth squalene on both blood and liver. Additionally, the study revealed an increase in the excretion of bile acid cholesterol and faecal matter,and it inhibited the activity of the HMG-CoA reductase enzyme, but the shark squalene did not show any of these effects. This suggests that the amaranth squalene may have been responsible for the hypolipide.

4.2 EFFECTS ON GLUCOSE LEVELS IN THE BLOOD

It appears that there is considerable disagreement over the effect that amaranth has on the levels of glucose found in the blood. Researchers have shown that eating either the grain or the oil may protect against insulin insufficiency, however some people with diabetes have found that the high glycemic index (GI) of the starch is a problem for them. Giancarlo and colleagues (2005) used an in vitro assay that consisted of the inhibition of beta-amylase to determine antidiabetic activity in two different kinds of A. caudatus seeds. Beta-amylase is an enzyme that plays a role in the digestion of starch and lowers the absorption of glucose. Amaranth oil and grain supplementation (A. esculentus L.) was investigated by Mi-Jeong et al. (2006a,b) using streptozotocininduced diabetic mice to examine its effects on glucose and lipid level of blood in mice. Diabetic rats, normal rats, diabetic rats fed amaranth grain, and diabetic rats fed amaranth oil were all studied over the course of three weeks. According to the findings, both blood sugar and serum insulin levels dropped.

Foods with a high glycemic index (GI) increase blood sugar and insulin levels. Reduced satiety from a high GI diet is associated with overeating, gaining weight, altered lipid profiles and insulin secretion, and an increased risk of developing cardiovascular disease and diabetes mellitus (Kendall CW et al., 2002). In addition to causing hunger and overeating, consuming foods with a high glycemic index (GI) may set off a hormonal cascade that reduces the amount of energy available for metabolism after eating. Consequently, eating foods with a low glycemic index (GI) may reduce the release of proteolytic counter-regulatory hormones including cortisol, growth hormone, and glucagon, thereby increasing protein synthesis (Majzoub JA et al., 1999).

Using a glycemic index (GI) of 107 and an insulin curve consistent with stimulation of insulin production, researchers (Guerra-Matias and Areas, 2005) compared an extruded amaranth product against white bread in 11 women. The authors draw the conclusion that a strong glycemic and insulin response is produced when amaranth flour is extruded, and advise patients who choose amaranth to treat celiac disease to adjust their meals accordingly to guarantee proper management of blood glucose.

More recently, Coelho KD et al. (2008) evaluated the in vitro digestibility of the starch of amaranth seeds and white bread, expanding on the aforementioned study. A GI of 87.2 was anticipated for raw seeds due to their high concentration of rapidly digested starch (30.7% db). In contrast to the white bread-like digestibility of the cooked, extruded, and popped preparation forms, the seeds in the flakes and toasted forms showed a higher GI (106 and 105.8, respectively). The nutritional value of the seeds remained the same after being cooked and extruded. There were no discernible variations seen in the digestibility of popped, flake, and roasted amaranth. The authors found that amaranth is a high GI diet because of its susceptibility to lose its crystalline and granular structure of starch during heat treatment operations, as well as its tiny starch granule size and low amount of resistant starch (1%).

4.3 IMPLICATIONS FOR THE TREATMENT OF HYPERTENSION

The existence of many proteins able to generate peptides that can inhibit ACE's function has been attested by multiple researchers in a series of papers. Researchers Leon-Galvan MF et al. (2008) looked for lunasin in amaranth grains, characterised it, and explored its anticarcinogenic characteristics. Several bioactive peptides with significant activities against cancer and hypertension were found in amaranth grains, leading the scientists to conclude that they may be a source of these compounds.

Defatted amaranth flour and its in vitro derivatives were investigated by Faria M et al. (2009) for their ACE-inhibiting activity and bile acid binding capacity. Both before and after in vitro digestion, the protein that had been hydrolyzed by the enzyme alcalase had the strongest inhibitory activity, suggesting that this process generates peptides that are resistant to digestive enzymes.

In 2009, Guerrero-Legarreta and colleagues investigated alcalase-hydrolyzed peptide fractions from albumin 1 and the globulin of amaranth grains (A. hypochondriacus) that suppress ACE. 40% of the inhibitory activity against ACE was found in the albumin 1 products after 15 hours of hydrolysis, while 35% of the inhibitory activity against ACE was found in the globulin after 18 hours of hydrolysis. In turn, Vecchi and A non (2009) have compiled data suggesting that globulin 11S, one of the most vital components of the A. hypochondriacus grain, also contains antihypertensive peptides. The antihypertensive peptides were mapped out using a computer method after a three-dimensional model of globulin 11S was constructed. Two tetrapeptides, ALEP and VIKP, were detected experimentally using in vitro ACE inhibition testing; their respective IC50 values were 6.32 mM and 175 M.

4.4 MALARIA-PREVENTIVE PROPERTIES

A. Hilou, O.G. Nacoulma, and colleagues (2006) conducted a study to determine whether or not the traditional uses of two Burkinabe folk medicine plants, spiny amaranth (Amaranthus spinosus L., Amaranthaceae) and erect spiderling (Boerhaavia erecta L., Nyctagynaceae), for the treatment of malaria were indeed effective. In a 4-day suppressive antimalarial experiment using mice injected with red blood cells parasitized with Plasmodium berghei berghei, the plant extracts demonstrated strong antimalarial activity. For Amaranthus spinosus and Boerhaavia erecta, we measured ED50 values of 789 and 564 mg/kg, respectively. In addition, the toxicity of the examined plants was quite low (1450 and 2150 mg/kg for Amaranthus spinosus and Boerhaavia erecta, respectively).

4.5 ANTIOXIDANT CAPABILITY

The presence of antioxidant activity has been documented in many fractions of amaranth. Two amaranth grain species, A. caudatus and A. paniculatus, were shown to have antioxidant activity in vitro in a -carotene/linoleic acid model system by Male et al. (2002). Using the Folin-Ciocalteu method, these researchers calculated that A. caudatus contained 39.17 mg/100 g of phenolic compounds, while A.paniculatus had 56.22 mg/100 g of phenolic compounds.

Conforti et al. (2005) studied two A. caudatus grain types (Oscar Blanco and Victor Red) to determine their biological antioxidant characteristics as well as the amount of oil, squalene, and phenolic compounds. The assessment of antioxidant activity was conducted by employing a lipid peroxidation assay. The four kinds exhibited varying levels of squalene content; yet, there were no statistically significant differences seen in terms of antioxidant activity. However, the a methanolic extract of both varieties exhibited antidiabetic properties, with A. caudatus var. Oscar Blanco demonstrating a 50.5% activity and A. caudatus var. Victor Red exhibiting a 28% activity at a concentration of 25 mg/ml.

The results of an investigation that Barton H. and colleagues (2008) carried out to evaluate the levels of phenolic and flavonoid compounds found in two cultivars of A. cruentus. Following this, the group that had previously been described carried out research on the antioxidant capacity, phenolic component levels, and anthocyanin content of A. cruentus grains and sprouts. The researchers found that after 4 days of germination, there was a considerable increase in the overall levels of phenolics and anthocyanins in the seeds. This was a finding that was made possible by the fact that the seeds were able to produce phenolics and anthocyanins. In addition, the seeds demonstrated an increased antioxidant capacity, which was measured by the ferric reducing ability of plasma (FRAP), the antioxidant capacity utilising 2,2'- azinobis(3-ethylbenzothiozoline-6-sulphonic acid (ABTS), and Diphenylpicrylhydrazyl. All of these tests were carried out in triplicate. The authors arrived at their opinion that the grains displayed a discernible presence of phenolic compounds on the basis of the observations that were provided. In addition, the sprouts were shown to be a significant source of the flavonoid rutin, which contributed to an increase in the overall antioxidant activity levels of the sprouts (Pasko et al., 2009).

Pasko et al. (2011) conducted a subsequent investigation to assess the impact of amaranth grains on oxidative stress levels in the plasma, heart, kidney, and pancreas of rats. The administration of fructose was utilised as a means to generate oxidative stress, which was observed through the elevation of malondialdehyde levels and the reduction of enzyme antioxidant capacity in both the plasma and specific tissues. The consumption of amaranth grains at concentrations of 310 and 155 g/kg of diet resulted in the restoration of enzyme activity and had an impact on oxidative stress by reducing malondialdehyde levels, increasing ferric ion reduction capacity in the plasma (FRAP), and enhancing the activity of antioxidant enzymes such as erythrocyte superoxide dismutase (eSOD), catalase (CAT), and glutathione peroxidase (GPx1). The findings of the study indicate that amaranth grains possess a modest protective effect against the alterations generated by fructose-induced oxidative stress in rats. This effect is observed in a dose-dependent manner and is attributed to the reduction of lipid peroxidation and enhancement of antioxidant capacity in the tissues.

5. CONCLUSION

The majority of research undertaken on the positive functions and actions of amaranth has been focused on experimental animal models. However, it is worth noting that the grain contains chemicals in its various fractions that possess potentially useful therapeutic characteristics. The presence of all of these bioactive compounds together in the entire grain of amaranth is likely to be responsible for its positive effects on human health. This is one of the fundamental ideas behind the notion of functional meals, which is based on the fact that bioactive substances can work in a variety of ways through a wide variety of metabolic pathways. The presence of all of these bioactive compounds together in the entire grain of amaranth is likely to be responsible for its positive effects on human health. This is one of the fundamental ideas behind the notion of functional meals, which is based on the fact that bioactive substances can work in a variety of ways through a wide variety of metabolic pathways. More work is needed to consolidate the mechanisms of action, especially in the human body, and to conduct epidemiological investigations. However, research that focuses on determining the absolute minimal amount of amaranth that must be consumed through one's diet in order to get the desired results is also something that should be pursued. However, due to the highly digestible starch that is present in both the popped and the extruded forms of the grain, care has been advised regarding the potential implications of the elevated GI. This is because the popped form of the grain contains less starch than the extruded version.

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