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A REVIEW ON DIETARY QUALITY, HEALTH ADVANTAGES, AND CONTEMPORARY USES OF PSEUDOCEREAL

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ABSTRACT

Pseudocereals have been used as a staple food by prehistoric societies. These plants stand out among underutilized foods because they do not belong to the cereal plant family but have characteristics and applications like other cereals. Because of its interesting traits, pseudocereals are becoming more important as crops. Buckwheat, chia, amaranth, and quinoa are among the most emblematic species. Pseudo cereals have gained a lot of attention because of their potential for use in the creation of gluten-free goods as well as their high-quality nutritional, phenolic, and phytochemical profiles. Further, compared to traditional cereals like wheat, rice, and maize, the amino acid profile and nutritional qualities of pseudo cereals are superior. Peptides generated from pseudocereal proteins have also been shown in earlier research to have anti-inflammatory, antioxidant, anti-cancerous, and anti-hypertensive effects. The existence of these intriguing qualities in pseudocereals increases interest in doing in-depth studies on their health advantages and dietary incorporation strategies. In this review, we discussed the pseudocereals such as quinoa, amaranth, chia, and buckwheat and their nutritive value, their effect on their on human health, how they use in celiac diseases, and the products which were made by pseudocereals.

Keywords: Amaranth, Buckwheat, Chia, Gluten-free, Pseudocereal, Quinoa.

1. INTRODUCTION

Cereal grains are essential to a balanced diet and regular exercise routine. Varied foods have different compositions, and each one has a unique set of macro and micronutrients. Food grains are high in one or more nutrients, such as protein, carbohydrates, minerals, or fats, while others are nutrient-dense and have optimal combinations of nutrients with good digestibility (most of the minor millets, quinoa, etc.).[1] The bioavailability of the nutrients in these grain products is high. Pseudocereals, on the other hand, are a kind of "under-utilized food" that consists of non-grass plant species that are not related to cereals but have many of their features and applications. There is growing interest in a grain substitute that may be useful for a variety of purposes. In recent years, there has been a worldwide explosion of interest in, and action toward, improving people's diets. The words "healthy," "whole," "natural," "minimally processed," and "whole grain" are all the rage.[2] Similarly, "gluten-free," "high in dietary fibre," "low carb," "digestibility," and "resistant starch" are all the rage within the realm of cereals. Pseudocereals are both appropriate and welcome in this setting, and their many health advantages are well recognized. As human consumption of pseudocereals rises, so too does the pressure on food manufacturers to create novel, convenient foods based on this ingredient. This calls for an understanding of not only the chemical make-up of pseudocereals, but also their functional and physical properties for processing.[2] Using just a few different crops has jeopardised global food security, which is especially concerning given that agriculture is so vital to national economies. The agribusiness sector is in difficulty because it must sustain high production and quality standards in order to feed the world's seven billion people.[3] Nutritional supplements, enrichment, biofortification, etc., provide the backbone of food security and must be used in conjunction with a multidisciplinary strategy to combat this issue. Those statistics enrage scientists and academics, driving them to seek out and share information on underutilized food sources. These grains are loaded with beneficial substances, including bioactive compounds, nutraceuticals, and vitamins, minerals, starches, and proteins. This piece

elucidates the potential of pseudocereals to substitute for, or be used in addition to, commonly consumed cereals. Due to its gluten-free or less gluten-containing nature, it may be safely used by those with celiac disease and has other health advantages. [4]

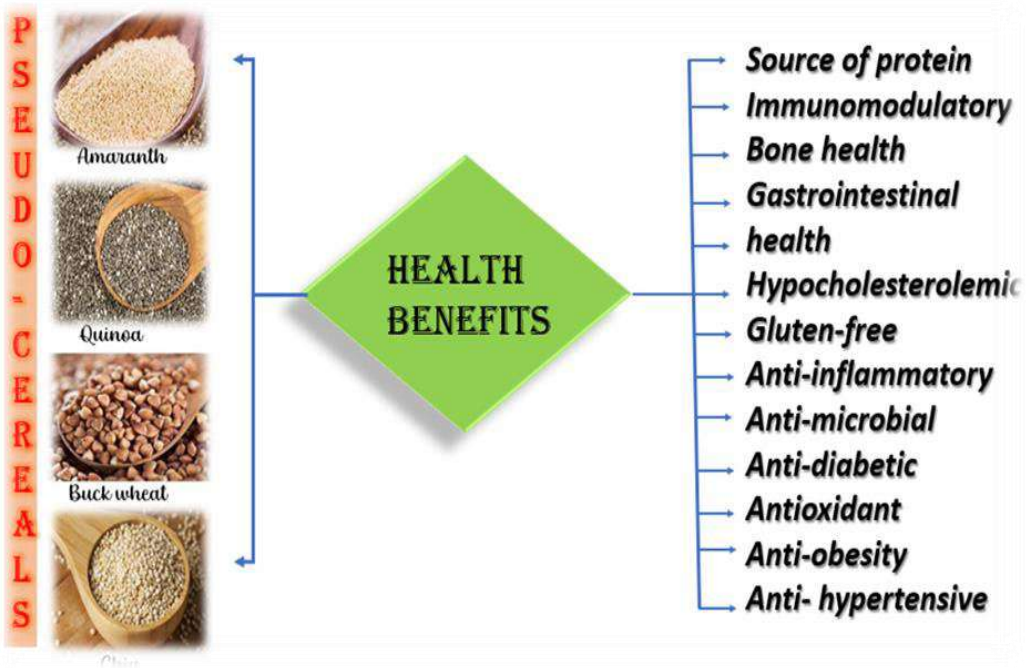

Fig 1: Health benefits of pseudocereals

2. TYPES OF PSEUDOCEREALS

In the diet of Human being, Pseudocereal plays a vital role in meeting the prerequisite of the population which is suffering from celiac diseases as well as other health consequences due to their wide length and depth of nutrients like Vitamins, Minerals, Fats, Protein, Carbohydrate and also nutraceuticals. Therefore, in this review paper, discussed only four types of pseudocereals i.e., Buckwheat, Chia seeds, Quinoa and Amaranth. All four pseudocereals are discussed below: -

2.1 Buckwheat: Buckwheat, a member of the genus Fagopyrum in the family Polygonaceae, is a pseudocereal that does not contain gluten. Fagopyrum tartaricum and Fagopyrum esculentum are two species of farmed buckwheat that are often used for human consumption. The global demand for it has been rising recently. People in the northern areas of India consume meals prepared with buckwheat flour during fasting days (such as Navaratri, Ekadashi, Mahashivaratri, Janmashtami, etc.) since consuming cereals made of wheat, rice, or maize is forbidden.[5] Proteins, lipids, vitamins, minerals, dietary fibers, organic acids, flavonoids, polyphenols, and inositol are all found in healthy quantities in buckwheat. Proteins have long been considered the body's "building blocks" due to their central role in formation, growth, and maintenance.[6] According to the aforementioned research, buckwheat is a nutritious option since it is higher in protein and contains more essential amino acids than common cereals like rice, wheat, and maize. In addition, lysine and arginine, two important amino acids, are present in buckwheat, providing the complete complement of amino acids needed for human health.[7] Buckwheat grains have greater protein content than other whole grains, with 11-14 grammes per 100 grams.

Fig 2: Buckwheat

Buckwheat has a lower glycemic index than other common grains, including rice, wheat, and corn. There are anti-nutritional substances in it, such as polyphenols and enzyme inhibitors, which slow digestion and aid in blood sugar regulation. For example, rutin and quercetin, both of which may be found in buckwheat, have been shown to improve the efficiency of antioxidant enzymes in the liver, hence lowering insulin resistance.[8] However, the research also found that buckwheat is a good source of D-chiro-inositol, a chemically manufactured insulin regulation component used to reduce blood glucose concentrations in diabetic individuals. Buckwheat is quite similar to barley in terms of size, shape, texture, and Flavour, but the absence of gluten is its key benefit.[9] Therefore, those who have celiac disease or who just want to avoid gluten may consume buckwheat without worry. Prevention of gastrointestinal disorders such as diarrhoea, bloating, constipation, leaky gut syndrome, and similar conditions is another benefit. Multiple studies have shown that buckwheat has beneficial effects on health, including as a hypocholesterolemia, hypotensive, hypoglycemic, neuroprotective, anti-obesity, and anti-aging diet.[10]

2.2 Chia: Chia seeds are a member of the mint family (Lamiaceae), specifically the Salvia hispanica species. They were first cultivated in Mexico. Whole chia seeds, flour, mucilage, and seed oil are just a few of the many ways that these tiny black and white seeds find use. The seeds are protected against microbial and chemical degradations because of the high amount of antioxidants in this nutrient-dense superfood. It is also a good source of gluten-free protein. It's an oil seed packed with nutrients, including carbs, proteins, fats, fiber, vitamins, minerals, and phytochemicals.[11]

Fig 3: Chia seeds

Protein is a well-known macronutrient, meaning it's used by the body to generate energy for several processes. Given the high protein content of chia seeds, they can be used to alleviate protein-energy malnutrition.[12] Previous research has shown the high content of cysteine, lysine, and methionine in chia seeds compared to the principal cereals,[13] demonstrating that chia seeds have a superior balance of amino acids. Consuming chia seeds, which contain a significant quantity of protein, on a daily basis has been shown to aid people with obesity, overweight, and linked health problems, including diabetes, according to another research. Chia seed, like other pseudocereals, does not contain gluten and may be eaten by those with gluten sensitivity or other dietary restrictions. Antioxidants, as everyone knows, are the magic ingredients that may put an end to free radical damage, making them invaluable in the fight against metabolic disease.[14]

2.3 Quinoa: Highly nutritious quinoa has been grown in the Andean area of Bolivia and Peru for the past 5,000-7,000 years. In light of its enormous potential, the United Nations proclaimed 2013 the International Year of Quinoa. Protein, all eight necessary amino acids, unsaturated fatty acids, a low glycemic index (GI), vitamins, minerals, and other healthy substances are abundant in quinoa, and the grain is naturally free of gluten. Quinoa may be prepared in a variety of ways and is simple to cook. The dietary and lifestyle choices of people all around the globe have been impacted by globalization and urbanization. Some chronic illnesses have increased in incidence due to a shift away from traditional dietary patterns heavy in complex carbohydrates, minerals, fibre, and phytochemicals.[14-16] Many scientists spend time investigating the potential health benefits of various foods and dietary components.

Fig 4: Quinoa seeds

Previous research has shown that the quinoa seed is the most nutritious component of the plant, but it has also been shown that the quinoa leaves are rich in phenolic chemicals, which have antioxidant and anti-cancer qualities. The ferulic, sinapinic, gallic, kaempferol, isorhamnetin, and rutin found in quinoa extracts have an anti-proliferative and anti-migratory action on prostate cancer cells.[17] It has also been suggested that these substances aid in decreasing the likelihood of developing neurodegenerative illnesses, cardiovascular disease, and diabetes. Patients with celiac disease have an intolerance to gluten protein, which is present in common grains, including wheat, rye, barley, and so on. It's well knowledge that quinoa doesn't contain any gluten protein, making it a safe option for those with celiac disease or who just want a gluten-free diet.[18]

Table 1: shows the clinical studies on Quinoa.

Compound	Dose	Model	Effect	Reference
Quinoa flour	WI	Investigation of quinoa flour	Significant scavenging of free radicals and ability to reduce ACE activity by 23.3%.	9
Quinoa flakes	25 g	overweight	Lowered serum triglyceride and cholesterol	19

		postmenopausal ladies	levels, with a trend toward reduced LDL and total cholesterol as well as elevated glutathione.	
Quinoa seeds	310 g/kg	Wistar male rats	Low-density lipoprotein (LDL), plasma levels of total cholesterol, glucose, triglycerides (TG), and malondialdehyde all decreased by 26–57–11–10.	20-21
Quinoa	50 g	Celiac patients	A positive experience with no worsening of celiac symptoms. There seems to be a rising trend in the improvement of histology parameters and total serum cholesterol.	22
Extract from seeds of quinoa	2,000 mg/kg	Wistar male rats	There is a general tendency toward reduced appetite, reduced body fat, and lower levels of triglycerides in the blood.	23

2.4 Amaranth: One of the first cultivated plants in the New World, amaranth has its roots in Mesoamerica. It's a member of the Amaranthaceae family, and it's a dicotyledonous pseudocereal. The Greek word "anthos" (flower) signifies "everlasting" or "unwilting," which is where the English term "Amaranthus" comes from. These days, it's grown and eaten all over the world, from India and Nepal to Eastern and Southern Africa, Indonesia, Malaysia, the Philippines, Mexico, and Central America. Amaranthus cruentus, Amaranthus hypochondriacus, Amaranthus caudatus, are all examples of the species of Amaranthus often cultivated for human use as a means of easing the nutritional benefits.[24-25]

Fig 5: Amarnath seeds

Nutrients such as tocopherols, squalene, flavonoids, phenolic compounds, dietary fibres, vitamins, minerals, and phytates give it the status of a superfood. In comparison to other common grains like wheat, rice, and corn, amaranth grains provide more protein overall but are lacking in the essential amino acid leucine. Previous research has shown that amaranth's protein composition is comparatively high in sulfur-containing amino acids, which are often scarce in pulses.[26] It is well knowledge that protein is essential for cellular development and maintenance, brain function support, digestive help, hormone balancing, and immune system maintenance. Earlier research showed that Amaranth oil might treat Helicobacter pylori-related conditions such as chronic gastritis and duodenal peptic ulcer.[24] Incorporating amaranth into your diet is a great way to satisfy your protein needs while adhering to a gluten-free lifestyle, and it's also a good option for individuals with celiac disease. Often referred to

as "free radical scavengers," antioxidants play an important role in maintaining health. They protect against cancer and other degenerative illnesses and help keep your heart healthy by blocking oxidation. Antioxidant properties in amaranth are a result of phenolics and flavonoids found in the plant. Extracts of Amaranthus flowers, leaves, and stems have been shown to have significant levels of antioxidant activity, with rutin serving as the primary radical scavenger.[27] The nutritional significance of Amarnath and buckwheat were shown in **table 2**.

Table 2: Nutritional Significance of Buckwheat and Amarnath

Grains	Moisture	Fat	Protein	Fibre	Carbohydrate	Reference
Buckwheat	-	7.2	15.7	4.2	63	[28]
	11.2	2.3	12.3	10.9	73.3	[29]
	6-9	6-8	13-18	4-14	63	[30]
Amarnath	6-9	6-8	13-18	4-14	63	[31]
	-	7.0	13.6	65.3	6.7	[32]
	11.29	7.2	13.56	6.7	65.25	[33]

3. PSEUDOCEREALS AND THEIR NUTRITIONAL SIGNIFICANCE

The great nutritious value of pseudocereals has earned them the name "grains of the twenty-first century." In addition to being a healthy source of protein, they are also rich in carbs and fibre. As a bonus, they include a plethora of essential nutrients.[34]

3.1 Carbohydrates: Pseudocereal grains, whose carbohydrate content ranges from 60-80% of the seed dry weight, are an excellent source of energy (dw). Quinoa, amaranth, and buckwheat each have between 65.0 and 75.0% starch by dry seed weight; quinoa has 58.1 to 64.2% starch, while buckwheat contains 54.5 to 54.4% starch. The amylose concentration of buckwheat starch is 18.3-47%, which is greater than that of quinoa (11-12%) and amaranth (7.8-34.3%).[35-36] Pseudocereals are a great choice for anyone looking to increase their intake of fibre in their diet. Common cereal grains fall somewhere in the range of 7.0–26.5 percent total fibre, whereas quinoa, amaranth, and buckwheat all have higher levels of fibre. The insoluble polysaccharides homogalacturonans (55-60%), rhamnogalacturonan-I (55-60%), highly branched xyloglucans (30%), and cellulose make up most of the dietary fibre in quinoa and amaranth.[37]

Buckwheat has a lower ratio of soluble to insoluble dietary fibre but a greater fibre content (17.8%) than other pseudocereals (0.5-0.28). In contrast to the major role that polysaccharides play in pseudocereal grains, mono- and disaccharides play just a supporting role. Pseudocereals mostly include the monosaccharides glucose, fructose, arabinose, and xylose, and the disaccharides sucrose and maltose. Both quinoa and amaranth have a greater simple carbohydrate content than cereals (between 3 and 5 percent), but buckwheat has a far lower level (0.8 percent). [13,38]

3.2 Lipids: Quinoa, amaranth, and buckwheat all have a much greater lipid content than other grains, ranging from 4.0 to 7.6 percent and from 10.6 to 7.4 percent, respectively. Specifically, the amount of polyunsaturated fatty acids in the oil is a key factor to consider when determining the oil's nutritional worth (PUFAs). Oil extracted from quinoa (71–84.5% unsaturated fatty acids), amaranth (61.0–87.3% unsaturated fatty acids), and buckwheat (80.1–80.9% unsaturated fatty acids) is believed to be of high nutritional value. Buckwheat's most abundant fatty acids are oleic acid (C18:1) and linoleic acid, whereas in amaranth and quinoa it is linoleic acid (C18:2, ω-6) and α-linolenic acid (C18:3, ω-3) that make up the majority. In addition, a trace quantity of saturated fatty acids may be found in the oil derived from pseudocereals. The percentage of total lipids made up of saturated fatty acids varies from 15.2 to 29.0 percent in quinoa, 20 to 30.9 percent in amaranth, and 18.8 to 19.5 percent in buckwheat.[16]

All pseudocereals have mostly palmitic acid as their primary unsaturated fatty acid. The ratio of omega-6 to omega-3 fatty acids is now seen as more relevant than the total fatty acid concentration in determining the nutritional value of lipid fractions. The incidence of atherosclerosis, obesity, and diabetes have been linked to an

imbalanced ω-6/ω-3 PUFAs ratio, which is extremely prothrombotic and proinflammatory. In fact, diets high in omega-3 PUFAs have been linked to lower rates of illness. When comparing quinoa oil (ω-6/ω-3 ratio: 4.7-19.6) with amaranth oil (ω-6/ω-3 ratio: 33.0-68.9), it is important to notice that quinoa oil has a higher nutritional quality due to its lower -6/-3 ratio.[39]

3.3 Minerals and Vitamins: Whole pseudocereal grains are rich in minerals because the bran contains the bulk of the cereal's mineral content. When compared to quinoa and buckwheat, amaranth has the greatest mineral content. Tartary buckwheat seeds were shown to have more minerals than regular buckwheat seeds in a comparison study. Pseudocereals are rich in the mineral's potassium, phosphorus, and magnesium. The high calcium concentration in amaranth may be of particular importance to give health advantages to celiac persons due to their increased vulnerability to osteopenia and osteoporosis.[40] Pseudocereals are fascinating because they have a high B vitamin concentration. Vitamin B6 and folate are both abundant in quinoa seeds, and the quantities found in the seeds are sufficient to meet the needs of both children and adults. Similarly, the riboflavin in quinoa seeds may meet 80% of a child's daily needs and 40% of an adult. The vitamin B profile of 14 gluten-free flours, including teff, millet, oat, chickpea, rice, chestnut, acorn, maize, buckwheat, and amaranth, was recently compared by. The greatest levels of vitamin B6 were found in amaranth, whereas vitamin B2 and B3 were found to be most abundant in buckwheat flours.[41]

Tocopherols (alpha, beta, and gamma isomers) and tocotrienols (alpha, beta, and gamma isomers) are two of the eight fat-soluble molecules that make up vitamin E. Both display antioxidant activity and are considered nutritionally necessary. The vitamin E activity of -tocopherol is superior to that of the other vitamin E isomers. Tocopherol acetate is the most abundant form of vitamin E in human tissue, accounting for over 90% of the vitamin's action; α-, β-,γ-, and δ-tocopherol dl-acetate are believed to have relative potencies of roughly 100:50:25:1. Quinoa has been shown to contain all four types of tocopherol, as well as α- and β-tocotrienols. It has been discovered that quinoa contains between 37.5 and 77.7 mg/kg of total tocopherol. Though quinoa has a similar overall tocopherol content with other cereal grains, its individual tocopherol profile is distinct, with γ-tocopherol and then α-tocopherol making up the bulk of the tocopherols. Amaranth seeds have been observed to have a content of total vitamin E that is three times lower than that of quinoa seeds. For example, -tocopherol predominated in amaranth seeds (7.7 mg/kg on average), followed by β-, α-, and γ-tocopherol.[42]

Table 3: Vitamin content of buckwheat, chia, quinoa, and amaranth

Parameter	Buckwheat	Chia	Quinoa	Amarnath
Vitamin A	-	54	14	0
Vitamin B1	-	0.62	0.36	0.116
Vitamin B2	-	0.17	0.318	0.2
Vitamin B3	-	8.83	1.52	0.923
Vitamin B5	-	-	0.772	1.46
Vitamin B6	-	-	0.487	0.591
Vitamin B12	-	0	0	0
Vitamin C	-	1.6	-	4.2
Vitamin D	0	-	0	0
Vitamin E	-	0.5	2.44	1.19
Vitamin K	-	-	1.1	0

4. BIOACTIVE COMPOUNDS

Bioactive chemicals are a class of non-nutrient plant components with emerging evidence of health benefits. Pseudocereal grains contain several types of bioactive substances, such as phenolic compounds, saponins, phytoecdysteroids, phytosterols, peptides betalains, polysaccharides, and bioactive proteins. Pseudocereals contain a wide variety of bioactive chemicals, some of which have just recently been shown to have biological effects.[43]

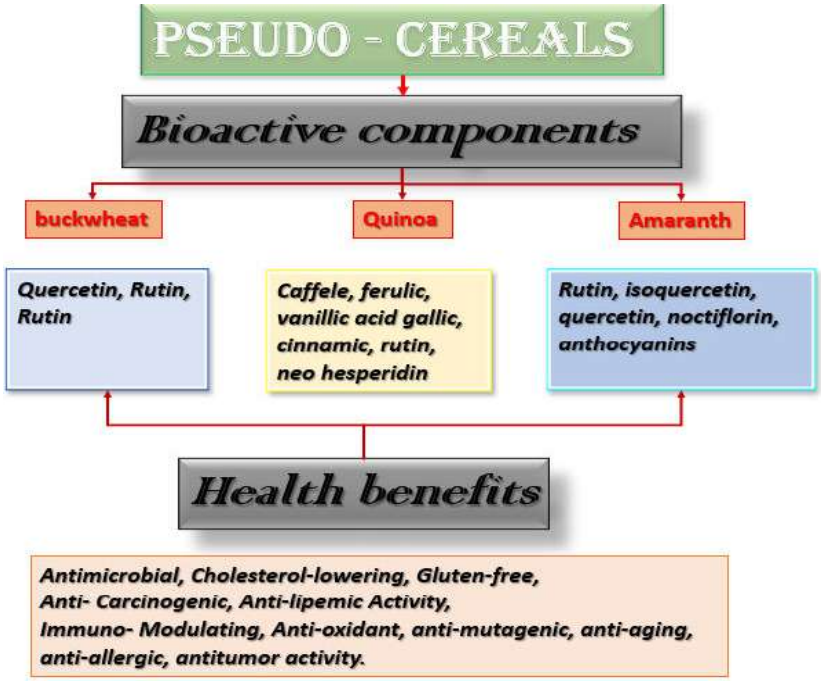

Fig 6: Bioactive compound of Pseudocereals

4.1 Phenolic Compounds: Due to their health advantages and role in preventing chronic illnesses, phenolic compounds have gained popularity in the past two decades. Dietary phenolic compounds maintain a healthy gut by balancing beneficial/pathogenic microorganisms.[44] Screening pseudocereal types for phenolic profile is a viable method for increasing nutritional quality in GF food design. Gallic and ferulic acids are the main free fraction phenolic components in seven quinoa types.[45] Flavonoids are quinoa's second-most prevalent phenolic group. Rutin, quercetin, and kaempferol derivatives are the primary flavonoids in quinoa seeds. Grains high in anthocyanins have been shown to reduce the likelihood of developing type 2 diabetes and/or obesity by inhibiting carbohydrate-digesting enzymes. This is important for designing GF functional meals.

Buckwheat is the best pseudocereal for phenolic compounds (275.5-532.0 mg gallic acid equivalents/100 g dw). Tartary buckwheat genotypes have a greater content of soluble phenolic compounds than ordinary buckwheat genotypes. Buckwheat's nutraceutical effects are due to eight flavonoids: orientin, rutin, quercitrin, quercetin, isovitexin, homoorientin, and vitexin. Tartary buckwheat groats contain 8.1 mg/g more rutin than ordinary groats (0.2 mg/g). Buckwheat seeds are the only pseudocereal found to contain proanthocyanidins (>70%).[46]

4.2 Triterpenoid Saponins: An aglycone, or pentacyclic C30 skeleton called sapogenin, is a key component of triterpenoid saponins. It is connected to two or more oligosaccharide chains that are between two and five hexoses or pentoses in length. There is just one sugar chain in monodesmosidic saponins, and it is fused at C-3. The 2 chains of sugar in bisdesmosidic saponins are joined by an ether bond at carbon 3 and an ester bond at carbon 28. Rare saponins with three sugar chains are called tridesmosidic. Several cultivars and species of quinoa and amaranth have shown that the seed saponin profile is very variable.[47]

Quinoa seeds, particularly the bran, contain 87 unique saponins, whereas amaranth seeds have just 15. Both pseudocereal grains contain saponins, and although most of them are bisdesmosidic, a tridesmosidic saponin has been isolated from Amaranthus caudatus. Glucose, galactose, arabinose, glucuronic acid, and xylose are often used to form oligosaccharide chains (with up to four monosaccharide units) that are then C-3, C-23, or C-28-linked to the aglycone.[48]

4.3 Phytoecdysteroids: Secondary metabolites called phytoecdysteroids to help plants fight off pests like worms and insects. These substances have a ring structure that consists of cyclopentane and perhydrophenanthrene, making them polyhydroxylated compounds. There is a wide variety in the chemical structure of phytoecdysteroids found in plants. Based on the number of carbon atoms in their molecules, these substances are classed as C27- and C28-phytoecdysteroids and they are mostly found in free and polar/apolar conjugated forms in the bran. It is well-established that phytoecdysteroids (138-570 g/g) can be found solely in quinoa, the only pseudocereal. In quinoa, the C-27 phytoecdysteroids, especially 20- hydroxyecdysone (20E, 184-497 g/g dw), have been shown to be the most prevalent among the 36 chemicals in this class. The C28-phytoecdysteroids, which include makisterone A, 24-epi-makisterone A, and 24(28)-dehydromakisterone A, are the second most common group of steroids in quinoa seeds. Many different health benefits may be attained through consuming quinoa's phytoecdysteroids.[49]

In addition to its potential as a natural alternative to dangerous anabolic steroids, phytoecdysteroids have drawn attention in other contexts. In mammalian models, 20E was shown to increase skeletal muscle synthesis, suggesting that it may boost athletic performance. Recent in vivo investigations have indicated that phytoecdysteroids in quinoa have antiobesity properties. To prevent high-fat-diet-induced obesity in rats, it was found that supplementation with either quinoa extract or pure 20E was effective. An increase in carbohydrate oxidation and faeces lipid excretion were blamed for the dramatic loss of body fat in this research. Memory impairments were seen in diabetic rats. However, it was found that 20E plays a protective function by increasing the brain's antioxidative capacity. [50-51]

4.4 Phytosterols: Phytosterols are triterpenoid compounds that resemble animal and human cholesterol. 27-30 carbon hydroxyl groups make up the chemical structure. 5 and 7 -sterols possess a double bond in the B-ring between C7 and C-8or C-5 and C-6. Buckwheat and Quinoa are high in 5-sterols, whereas amaranth contains 7-sterols. -sitosterol, campesterol, and stigmasterol make up most of quinoa and buckwheat's 5 -sterols.[52-53] Buckwheat oil also contains avenasterol, 7-stigmasterol, cycloartenol, and 24-methylenecyclo-artanol. Spinasterol (73.7%) dominates amaranth grain phytosterols, followed by 7-campesterol (3.5%), 7 -stigmasterol (11.9%), 5 -stigmasterol (0.9%), 5-campesterol (1.4%), and 7-avenasterol (2.1%). Compared to buckwheat and amaranth, quinoa's phytosterol concentration (38.8-41.2 mg/100 g) is lower. Several nations have authorized phytosterol and LDL cholesterol health claims.[55] Evaluated that phytosterols have been shown to reduce triglycerides in both normal and hypertriglyceridemia patients, according to evidence from 12 randomized controlled studies.[54-55]

5. EFFECT OF PSEUDOCEREALS ON HEALTH

Considering the nature and qualities of pseudocereals, there is currently a dearth of in vivo models of scientific data supporting health claims. Using pseudocereals or their bioactive components has been associated with a reduced risk of obesity, pre-diabetes, and diabetes. In a diet-induced obesity mouse model, a high-protein amaranth diet was shown to change the composition of the gut microbiota and to decrease body weight and food intake by decreasing rat plasma ghrelin concentrations and increasing cholecystokinin levels and postprandial leptin.[56] Hydrolysates of amaranth protein were shown to significantly lower blood pressure in rats with spontaneous hypertension, whereas amaranth protein boosted plasma insulin concentrations and enhanced glucose tolerance in Wistar rats. Tartaric buckwheat protein was demonstrated to have hypocholesterolemic and anti-inflammatory properties. In Wistar rats and obese diabetic mice, quinoa prevented hyperglycemia by decreasing LDL-cholesterol and total cholesterol.[57]

Quinoa consumption in the latest model was associated with a decrease in total cholesterol accumulation and hepatic steatosis in the liver. Extracts high in phytoecdysteroids from quinoa have also been shown to be beneficial in a diet-induced obesity mouse model, where they reduced decreased the expression of genes involved in fat storage, attenuated mRNA levels of inflammation and insulin resistance, and adipose tissue.[58-59] The researchers also found an increase in energy expenditure, glucose oxidation, and faecal fat excretion without an accompanying increase in stool volume. Insufficient research has been conducted on the benefits of consuming pseudocereals in humans. Researchers have shown that consuming quinoa may change cardiovascular and metabolic markers in persons of diverse body types. The modulatory effects of buckwheat on metabolic and

cardiovascular markers have been shown in both healthy individuals and diabetic patients, and these effects are seen whether buckwheat is taken abruptly or persistently.[60-61]

6. CELIAC DISEASES

Gluten is a general word for proteins (prolamins) present in the endosperm of several cereals, including wheat (gliadins), rye (secalins), and barley (hordeins).[62] Celiac disease (CD) is an autoimmune illness that causes intestinal mucosal damage due to dietary gluten. Although it was first reported in places with a mostly Caucasian population, this condition is widespread around the globe. CD has a 1.4% worldwide seroprevalence, with a prevalence of 0.7% among those who have had a biopsy confirm the diagnosis. CD can only be treated by following a gluten-free diet (GFD). However, sticking to a GFD or making nutritionally sound meal choices is typically difficult for the patient. Patients benefit from having a nutritionist monitor their progress on a frequent basis [63] because of the risk of nutritional deficiencies and excesses associated with this diet (such as fibre and saturated fat, respectively). Pseudocereals are a category of non-grass and naturally gluten-free plants that may lessen the restrictions placed by a GFD on the consumption of tubers, cereals, and their derivatives. The great nutritional value of pseudocereals, including amaranth, quinoa, millet, and buckwheat, has led to their increased acceptance as part of a GFD. Pseudocereals are examined as a replacement to diversify and optimise a GFD [64] due to their high starch and fibre content as well as their high biological value proteins.

Pseudocereals' protein bioavailability is greater than that of regular cereals and on par with that of animal protein. Excluding specific cereals from a GFD may result in a loss of protein sources.[65] Therefore, this is important to consider when deciding whether or not to include pseudocereals in the diet. Amaranth and quinoa have been shown to have higher quality more complete protein profiles, so too, with fibre. The fibre level of buckwheat is very high compared to that of other cereals and pseudocereals (quinoa and amaranth). Buckwheat is a great addition to a GFD since it may help combat the common problem of fibre deprivation among these people. Pseudocereals also differ significantly from ordinary cereals like wheat in that they have a lipid content that is two to three times greater. Together, the bulk of these lipids are unsaturated, increasing their nutritional value. These pseudocereals are a good alternative for a GFD since these nutrients are typically deficient in CD patients.66

According to the National Nutrient Database for Standard Reference, (USDA)[67] comparing pseudocereals to regular wheat per 100 g shows that the latter is unique due to its greater selenium content. Buckwheat, quinoa, and amaranth provide twice the protein of wheat. Bulgur and buckwheat contain more fibre than wheat. Amaranth has greater mineral content than wheat and other pseudocereals. Pseudocereals include bioactive chemicals not included in the nutritional definition, as well as bioactive minerals, vitamins, fatty acids, and peptides. Polyphenols, saponins, phytosteroids, phytosterols, and betalains have antioxidant, anti-inflammatory, antidiabetic properties, and anti-cancer. Together with the nutritional density of pseudocereals, phenolic compounds have been shown to have a role in the beneficial health impacts of these foods.[68]

7. POTENTIAL AND USE OF PSEUDOCEREALS IN GLUTEN-FREE (GF) FOOD PRODUCTION

Novel GF foods are a key trend in the food sector. This market is projected to increase by 9.1% from 2019 to 2025. The increased prevalence of gluten-related disorders in industrialized nations drives the growth of the worldwide GF business. The rising popularity of GF products among health-conscious consumers who choose to avoid gluten is a major factor in the market's rapid rise. While studies have shown that a gluten-free diet may help individuals with gluten-related disorders, many GF goods are of low quality from a nutritional standpoint.[69] The protein, mineral, and fibre content of gluten-free products are often lower than that of their gluten-containing counterparts, but the fat, sugar, and salt content is typically greater. With more people looking for gluten-free options, scientists are putting forth more effort to develop new, nutritious GF options. Gluten-free goods have difficulty enhancing their bioactive, technical, and sensory qualities. Common grains used to make GF products include rice and maize. Pseudocereals, which are naturally gluten-free grains that are high in nutritional content and a source of bioactive compounds, have emerged in recent years as a new component in GF formulations. The bitter pericarp of quinoa seeds must be removed before the seeds can be used. Both the embryo and endosperm of

the quinoa seed are protected throughout the soaping process. To utilize buckwheat in GF meals, the hulls must be removed, while amaranth seeds must be ground into flour.[69-70]

7.1 Gluten-Free Bread: Gluten is a vital constituent that gives bread its technical properties. Hence GF bread is of poorer quality and acceptance. GF bread has poor gas retention during fermentation, resulting in limited volume, crumbly texture, and hard crumb. GF bread lacks the rheological, texture, and baking features of gluten breads. Besides technical issues, gluten-free breads are poorer in vitamins, fibre, protein, and minerals. In order to increase the nutritional and technical aspects of GF breads, research researchers have concentrated on using pseudocereals, which are nutrient-dense grains with high albumin and globulin content. The inherent emulsifiers in the pseudocereal flours gave these loaves a softer texture, and the volume of the quinoa and buckwheat loaves was greater than that of the control loaves.[71]

The addition of pseudocereals to bread increased its dietary fibre, protein, calcium, iron, vitamin E, phenolic content, and antioxidant activity. Another study discovered that the magnesium, phosphorus, potassium, phenolic compounds, and antioxidant potential of gluten-free bread were all improved when maize starch was substituted with 40% buckwheat flour. Breads made with rice as the foundation may have their starch retrodegraded, their anti-staling characteristics improved, and their flavour enhanced by adding 10-30% husked buckwheat. Antioxidant activity in gluten-free rice-based breads was shown to be increased after being fortified with buckwheat flour. High-quality gluten-free loaves may be made by adding amaranth flour.[72-73]

7.2 Gluten-Free Beverages: Pseudocereals are the popular source material for fermented and therapeutic drinks. Beer is a popular fermented drink. Several researches have examined quinoa, amaranth, and buckwheat for making GF beer-like products. Buckwheat beer has a good smell, flavour, texture, tingle, and bitterness[74] made bottom-fermented GF beers with buckwheat and quinoa malts and found comparable viscosity and pH. Buckwheat beer-like products had fermentability, wort pH, soluble protein content, and volatile chemicals similar to barley beer; however, quinoa beers did not. quinoa beers have similar viscosity and pH as barley beer.[75] Quinoa and buckwheat drinks were well-received, although the latter more so. Buckwheat beer-like beverage resembles barley products, yet quinoa has distinct nutritious characteristics, nutty fragrance, and black color. Both pseudocereals exhibited brewing potential, and the scientists said.[76]

Pseudocereals may be fermented into non-beer-like drinks. Using quinoa and soy extracts in varying amounts, symbiotic drinks were created. Eighty participants tested several formulations, and those containing 30% quinoa had the lowest hysteresis, maximum sensory acceptance, chemical composition, and largest desire to purchase. Quinoa seed water extract replaced 25-100% of buffalo skim milk in fermented drinks. Authors found that adding 75-100% quinoa to fermented beverages improved taste, texture, colour, and appearance and increased amino acid and mineral content[77] fermented Rosada de Huancayo and Pasankalla quinoa varietals. Both kinds were good raw materials for fermented drinks, strong in protein, fibre, vitamins, and minerals, while Pasankalla produced beverages with more protein, less saponin, and less viscosity loss during fermentation. Both beverages showed steady microbiological loads throughout storage (28 days).[77]concluded that celiac patients and those with gluten-related disorders need special attention from dietitians and nutritionists, who should take note of their gluten-free dietary preferences. Long-term follow-up and randomized clinical studies should be used to assess the impact of suitable eating patterns on clinical outcomes, and new dietary strategies should be developed.[78]

8. FUTURE PERSPECTIVES

Significant strides have been made in improving pseudocereals via biotechnology, breeding, and agronomic approaches in order to increase productivity, yield, and climate resilience. More study into these areas is needed so that these grains may replace traditional cereal grains in industrialized nations, both in terms of production and commercial end-use. Pseudocereals like quinoa, amaranth, and buckwheat are gaining appeal among consumers and researchers due to their ability to thrive in harsh environments while yet maintaining their nutritional value. In addition to their high nutritional value, the lack of gluten in these pseudocereals makes them a viable choice for creating tasty GF goods that guarantee proper nutrient intake in the ever-increasing number of patients with celiac

disease. Recently, there has been a surge in the availability of gluten-free, pseudocereal-based goods that are nutritionally sound. However, the texture and sensory qualities of foodstuffs made with pseudocereals are often inferior to those of their gluten-containing counterparts. Numerous bioactive components, such as saponins, phenolic compounds, phytosterols, Phytoecdysteroids, polysaccharides, and bioactive proteins and peptides, may be found in pseudocereals. These chemicals are thought to be primarily responsible for the healthful effects on various bodily systems associated with eating pseudocereals, which in turn help to enhance human health and lower the risk of many chronic conditions such as cancer, cardiovascular disease, diabetes, and aging. Although some bioactive chemicals have been shown to have positive health effects, there is currently a lack of conclusive data to support these claims. More research is required. Phytochemical bioavailability and interactions are two more interesting topics to explore. Pseudocereals would also be more valuable as a component of a healthy diet if well-controlled human studies were done to verify their health benefits in the general population. Therefore, most of the pseudocereals' nutritional and physiological potential remains untapped.

9. CONCLUSION

One of the most interesting developments in the agri-food sector is the emergence of nutraceutical foods and related products. There has been a recent uptick in the production of nutritionally beneficial products made from pseudocereals, which may be useful for celiac disease patients. Major pseudocereals like amaranth, buckwheat, chia seeds, and quinoa are well known for their nutritious nutrient profiles, which include a wide variety of vitamins, fats, dietary protein, minerals, antioxidants, dietary fibers, and bioactive components with properties like anti-diabetic, cardioprotective, anti-obesity, immunomodulatory, hypocholesterolaemia, anti-inflammatory, and maintenance of gastrointestinal disorders. The starches and chemicals used to produce gluten-free products leave those with celiac disease lacking in vital nutrients. Providing a celiac patient with gluten-free pseudocereals like buckwheat, amaranth, quinoa, and chia seeds not only prevents malnutrition but also allows these neglected food grains to thrive. Only very few research exists on the characteristics of pseudocereal. As a result, knowledge on their functionality in establishing end product qualities is limited and therefore, further studies are needed.

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