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A Diminutive Review on "Quinoa Seed's Nutrient Content, Biological Active Compounds and Potential Food Applications

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ABSTRACT

Cereals are regarded as a vital component of the human diet. They supply roughly half of the world's energy. Quinoa (*Chenopodium quinoa* Wild) is a very nutritious plant that has been dubbed "one of the grains of the 21st century" due to its nutritional and functional qualities as well as its ability to withstand harsh weather conditions. It has gained widespread recognition as a superfood due to its significant nutritional and physiological benefits. The current review offers a brief introduction to the nutrients, mineral makeup, amino acids, polyphenols, and bioactive ingredients of quinoa. It is revealed that quinoa contains a wealth of essential components, including vitamins, minerals and amino acids, which directly contribute to its remarkable nutritional value. Its antioxidant properties and unique composition of physiologically active chemicals, such as polyphenols and other compounds, increase its potential as a functional meal. The conclusion of this review is to provide a useful understanding of the potential nutritional and health benefits of quinoa as well as its potential culinary usage. Furthermore, fermented quinoa has a high biological and nutritional value that may be utilized to create a variety of functional food products that are highly palatable to consumers and have positive health effects.

INTRODUCTION

Countries with rapidly expanding populations must discover new sources of nourishment. Despite being readily available to the local population and having a high nutritional value, indigenous crops in the Andes are sometimes overlooked. While some of the crops are wild and regarded as weeds, others are grown [1]. Quinoa (*Chenopodium quinoa* Wild), a very nutritious plant with 250 variants worldwide, is a member of the Amaranthaceae family. It is categorized according to the form of the plant or the colour of the fruits and plants. In Europe, North America, Asia and Africa, this grain may be planted. In Europe, North America, Asia, and Africa, this grain may be planted. Due to its remarkable nutritional profile and adaptability as a food source, this pseudo-cereal has garnered a lot of interest lately. It became an essential part of many indigenous societies' diets. It is a vital staple that can improve food security and nutrition, especially in areas experiencing agricultural difficulties, due to its remarkable

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resilience and ability to grow in a range of environmental obstacles, such as high altitude and nutrient-poor soil. In both cold (-5°C) and hot (up to 35°C) regions, quinoa has shown a strong resistance to salty, acidic, or alkaline soils [2]. Quinoa was brought to South Asia recently, and because of its adaptability to a variety of climates, its production there is becoming more and more popular. Its ability to thrive in both dry and semi-arid environments is a result of Pakistan's shifting agro-ecological zones. Farmers must choose a quinoa variety that is appropriate for their environment in order to cultivate it successfully. To promote healthy growth and a suitable supply of nutrients, plants should be spaced appropriately apart. Quinoa is a drought-resistant crop that requires little irrigation, making it a sustainable agricultural option in arid regions of South Asia. Due to its high nutritional value and environmental adaptability, it has been cultivated as a new alternative crop in many places [3]. The method of cultivation includes preparing soil that drains properly and planting seeds 1-2 cm deep (Figure 1).

Figure 1: Quinoa Plant and Its Seeds

Its low glycaemic index makes it an excellent meal choice for diabetics because it helps control blood sugar levels. Because it includes antioxidants, which also improve general health, consuming it greatly reduces the risk of acquiring chronic diseases. Quinoa serves as an intriguing crop with a long history and a lot of possibilities for modern diets. Its numerous health advantages make it a wonderful addition to a variety of culinary techniques, and its extensive cultivation can help to improve food security and nutrition in the South Asian region [4]. Quinoa is a gluten-free food, and studies have demonstrated that regular consumption of quinoa improves small intestine health in people with celiac disease, allowing intestinal villi to heal more quickly than with a simple gluten-free diet [5].

Despite quinoa's recognized nutritional superiority and adaptability to harsh environmental conditions, comprehensive reviews integrating its nutritional composition, polyphenolic profile, biologically active compounds, and potential food applications particularly in the South Asian context remain limited. Existing studies often focus on isolated components rather than providing a holistic understanding of its functional and therapeutic potential. Moreover, variability in genotypes and environmental influences on nutrient composition requires further consolidation. Therefore, an updated and integrative review is necessary to highlight quinoa's full nutritional and health-promoting potential.

Varieties Found in Pakistan

Quinoa is a nutritious crop that has great adaptability to a variety of environmental situations. In Pakistan, it has a great chance of expanding. Its remarkable resistance and durability imply that it might flourish in Pakistan's many climates, even though the majority of research has concentrated on its growth in the Andes. It can withstand harsh weather conditions as salt, drought, and frost. Because of this, quinoa is a great choice for Pakistan's underserved regions [6]. According to research, quinoa agriculture is more affected by soil sodicity a high percentage of sodium ions, than by salinity. Genotypes such as A1 and A7, on the other hand, exhibit improved nutritional quality and stress resistance, making them suitable for regions impacted by salt. Quinoa genotypes grown in Pakistan have been the subject of recent research. C. quinoa V7, V2, and V1 are among them. In Pakistan's food industry, quinoa's potent nutritional profile, which includes high levels of protein and fatty acids, can provide enormous advantages for human consumption. It may find application in the pharmaceutical, food, and animal feed sectors [7]. Because of its broad leaves and starchy, dicotyledonous seeds, quinoa is categorized as a pseudo-cereal crop, which means it is not a cereal. The FAO views quinoa production as a way to fight famines because of its natural resistance to dry soils [8]. It is extremely suited to the various soil types and climate zones, having been domesticated in the Andes. Quinoa is a potential substitute for increasing food security in Pakistan and provides a path towards sustainable agriculture.

Nutrients of Quinoa

Quinoa is well-known for its resilience, but it also maintains its position as a superior nutritional and health food. For vegans and vegetarians, it is a wonderful source of nutrients. the chemical makeup of quinoa seeds was as follows: 62.07% carbohydrates, 14.40% protein, 6.88% fat, 5.12% crude fibre, 2.63% ash and 8.90%moisture [9]. Quinoa is regarded as one of the best sources of vegetable protein (12–23%); its protein level is higher than that of actual cereals like rice, wheat, and maize and comparable to that of milk. Additionally, quinoa contains a high percentage of starch (52–60%) and a low percentage of amylose (7–11%). Additionally, quinoa has a greater dietary fibre content than other cereals [10]. Protein, dietary fibre, vitamins (particularly B vitamins and vitamin E), and vital minerals including calcium, iron, potassium, and magnesium are also abundant in it [11](Table 1).

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Table 1: Nutritional, Mineral and Vitamin Composition of Quinoa Seed

Variables	Parameters	Values
Nutritional Composition (g/100g)	Moisture	8.9
	Ash	2.63
	Fat	6.88
	Fiber	5.12
	Protein	14.4
	Carbohydrates	62.07
	Energy Kcal/100g)	464.6
Minerals (mg/100g)	Calcium (Ca)	70
	Potassium (K)	855
	Sodium (Na)	2.7
	Phosphorus (P)	462
	Zinc (Zn)	3.2
	Iron (Fe)	6.3
	Magnesium (Mg)	161
	Manganese (Mn)	3.5
Vitamins (mg/100g)	Riboflavin (B2)	0.60
	Folic Acid (B9)	6.80
	Niacin (B6)	1.24
	Alpha Tocopherol (E)	2.01

Amino acids

A significant source of dietary proteins is the grain quinoa [12]. The proteins found in quinoa grains are globulins (37%) and albumins (35%), with a lesser proportion of prolamins. Quinoa's protein content is on par with that of casein, a protein found in milk. Tryptophan, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tyrosine, and valine are among the necessary amino acids that are found in quinoa proteins [13]. For this reason, it is considered a complete food. Protein consumption is a challenge for communities that rarely eat animal proteins; consequently, plant-based proteins should be an integral part of their diet. In this sense, quinoa-based products are a good choice because, in contrast to other traditional cereals, quinoa does not significantly lose protein content during industrial processing. Furthermore, quinoa's organic value surpasses that of other conventional cereals due to the amino acid makeup of its proteins. Furthermore, lysine is regarded as the first limiting amino acid and is a vital nutrient for children, as it can boost immunological function and support human development [14] (Table 2).

Table 2: Amino Acids Composition of Quinoa Seed

Amino Acids Profile	Concentration (g/100g Protein)
Glutamic acid	17.30
Aspartic acid	10.54
Arginine	9.71
Leucine	6.88
Lysine	6.30
Glycine	6.26
Serine	5.62
Alanine	5.53
Phenylalanine	4.52
Threonine	4.41
Histidine	4.09
Valine	3.67
Tyrosine	3.66
Proline	3.54
Isoleucine	3.02
Methionine	2.27
Half cystine	1.39

Polyphenolic profile

The phenolic profile of quinoa seeds powder by HPLC which are Protocatechuic, kaempferol, caffeic, syringic, vanillic, ferulic, chrysin, sinapic, p-coumaric apigenin-7-glucoside, rosmarinic and cinnamic equal to 21.2, 13.6, 49.0, 22.8, 285.9, 3059.2, 9.3, 244.9, 65.8, 52.1, 14.6, 342.1, 107.7 and 44.1(µg/100g), respectively (Table 3).

Table 3: Polyphenolic Profile of Quinoa Seed Powder

Phenolic Profile	Concentration (µg/100g)
Ferulic	3059.2
Rosmarinic	342.1
Vanillic	285.9
Sinapic	244.9
Cinnamic	107.7
p-coumaric	65.8
Rutin	52.1
Caffeic	49
Apigenin	44.1
Syringic	22.8
Protocatechuic	21.2
Apigenin-7-glucoside	14.6
Kaempferol	13.6
Chrysin	9.3

When compared to other phenolic compounds that are present in moderate concentrations, like vanillic and sinapic, it is evident that rosmarinic and ferulic acid are found in the highest proportions. However, data in the same table showed that the lowest levels of kaempferol and chrysin are present. Phenolic is a broad and varied class of chemicals that have at least one aromatic hydrocarbon ring joined to a hydroxyl group or groups. Because of their high structural stability, phenolics have substantial antioxidant properties [15]. Quinoa has a lot of polyphenols, which are significant byproducts of biologically active secondary metabolism in plants. They have a structure that includes one or more aromatic rings and hydroxyl groups. Quinoa's functional qualities and flavour are influenced by the amount of these phenolic chemicals it contains. Touil *et al.*, (20124) used the HPLC-DAD analysis to identify the phenolic compounds of the various extracts of quinoa

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genotypes [16]. They found seven phenolic compounds, which may be categorized into four families: coumarins, stilbenes, flavonoids and phenolic acid. Higher phenolic contents and antioxidant activity are found in darker quinoa seeds. Through their regulation of the gut's microbial balance, dietary phenolics contribute to gut health maintenance. According to Melini and Melini, (2022), individual phenolic acids have important anticancer, anti-inflammatory, anti-obesity, antidiabetic and cardioprotective properties because they enhance metabolism and cell signalling [17]. The environmental conditions at the planting location also have an impact on the polyphenol content of quinoa. Phenolic compounds have attracted a lot of attention in the past 20 years because of their potential to prevent chronic diseases and provide other health advantages [18].

Biologically Active Compound

Carbohydrates that are glycosidic linkages bind with high molecular weight, called polysaccharides, which have a range of biological functions. Starch and non-starch polysaccharides are the two main types of quinoa polysaccharides. About 60% of it is crude starch, and of those starches, amylopectin has a larger proportion than amylose. Microorganisms in the large intestine can partially digest and metabolize dietary fibre, a form of carbohydrate with nutritional functional activity that cannot be broken down by the human small intestine. Quinoa contains between 7.7% and 9.7% total dietary fibre and between 1.3% and 6.1% soluble dietary fibre. People with celiac disease symptoms can effectively address gluten-free fibre shortages in their diet by substituting fibre-rich, gluten-free whole grains like quinoa for refined grains [19]. Several other bioactive substances, each with unique health advantages, include saponins, polyamines, polyphenols, phytosterols, and bioactive peptides. Saponins are prevalent in the quinoa seed husk. Because saponins are bitter, they are generally considered to be anti-nutritional. They may also lower cholesterol, facilitate nutrition absorption, and increase the permeability of the cell membrane. Additionally, saponins are used as fungicides, insecticides, and detergents [20]. Quinoa also contains phytohormones, including genistein and daidzein, which have antioxidant properties, boost bone density, and preserve vascular health [21]. Polyamines like spermidine and spermine give quinoa its "earthy" flavour. On the other hand, bioactive peptides, phytosterols, and polyphenols have anti-inflammatory, antibacterial, and antioxidant qualities. According to Hernández-Ledesma (2019), it is also a good source of fatty acids, such as palmitic, oleic, linoleic, and α-linoleic acids [22].

Potential Food Applications of Quinoa

Quinoa and other ancient foods have been saved by the growing demand for healthier and more functional diets. A pseudo cereal that was crucial to many ancient societies was quinoa. It is becoming more and more important in the markets because of its superior nutritional value compared to many of the cereals that are a staple of modern diets. Ascorbic acid, protein, and minerals like P and K are all abundant in it [23]. The production of synbiotic foods, lactose-free fermented foods, gluten-free fermented foods, and bioactive peptides, as well as their use as food additives in fermented dairy and non-dairy foods, was all made possible by quinoa seeds because of their functional ingredients [24, 25] (Figure 2).

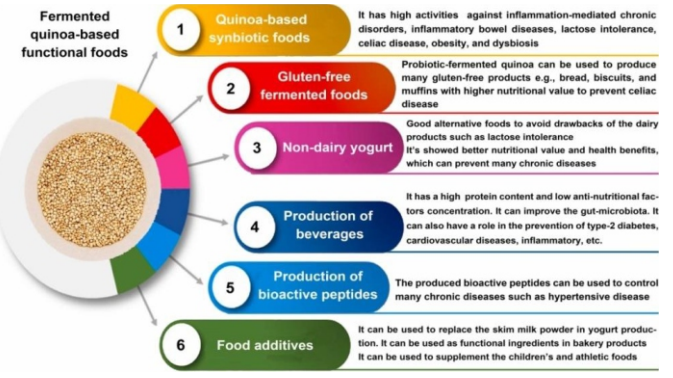

Figure 2: Functional Food Products by Fermented Quinoa

Limitations and Future prospects

Although quinoa demonstrates remarkable nutritional and functional properties, most available evidence is derived from laboratory-based or compositional studies, with limited large-scale clinical and long-term dietary intervention research. Variations due to genotype, processing methods, and environmental conditions also influence its nutritional profile. Future studies should emphasize human clinical trials, bioavailability assessments of key bioactive compounds, and development of innovative quinoa-based functional foods. Expanding research in diverse agro-climatic regions will further support its role in sustainable food security and public health improvement.

CONCLUSIONS

Quinoa is a high-nutritional, historically significant pseudo cereal that can withstand environmental stress. A substantial portion of the daily requirements for key nutrients, primarily amino acids, vitamins, minerals, carbohydrate, fibre and antioxidants, are present in quinoa. Its capacity to nourish millions of undernourished individuals globally has been acknowledged. Additionally, quinoa is gluten-free, and it is generally safe for those who have celiac disease. Fermenting quinoa enhances its nutritional and sensory qualities and yields useful functional foods with increased biological activity. In order to effectively improve public nutrition and health, new

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functional foods that incorporate quinoa into contemporary diets should be developed.

Authors' Contribution

Conceptualization: MKS
Methodology: MKS, SA
Formal analysis: NZ, KF, AK
Writing and Drafting: HMJ
Review and Editing: HMJ, NZ, KF, AK, MKS, SA

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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