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A Comprehensive Review on Quinoa

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This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Quinoa (*Chenopodium quinoa Willd*) is pseudocereal that has survived in the Andean region's tough bioclimatic conditions since time immemorial. This crop is still widely grown in the Bolivian and Peruvian areas. Many countries are expressing interest currently because of its wide agro-ecological adaptability and its ability to provide food security in developing countries. Quinoa is also incredibly healthy due to its high protein content, which includes all essential amino acids, gluten-free, PUFA and mineral content, which includes calcium, magnesium, iron, sodium, and potassium, as well as flavonoids. Based on its diverse qualities, FAO declared 2013 to be the **"International Year of Quinoa."** Gluten free cereal grains with great amounts of nutrients and can replace wheat in various food products. Quinoa is one of those cereals which have all – in it.

Keywords: Quinoa; pseudocereal; nutridense; gluten free.

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1. INTRODUCTION

Quinoa (*Chenopodium quinoa Willd.*) plant belongs to the *Chenopodiaceae* family, with an approximate of 250 species of this family all over the world and it is an endemic plant peculiar to South America. In 1778, Wildonow first illustrated quinoa botanically as it was domesticated by people living in the Andes particularly in Peru and Bolivia about thousands of years ago [1]. The oldest archeological quinoa remains date back to 5000 BC. While local languages use different names such as supha, suba, jupha and dahue to refer to quinoa, it is called quinoa especially in Bolivia, Peru, Ecuador, Argentina and Chile.

Quinoa is usually referred to as a pseudo-cereal since it is not a member of the Gramineae family but it produces seeds that can be milled in to flour and used as a cereal crop it is highly resistant to weather, climate, and soil conditions [2]. It is called as ‘golden grain’ because of its ability where it can grow in adverse conditions like cold, drought and salt and can adopt to high temperature [3]. It can grow in a place with annual rainfall within a range of 200-400 nm and even at high precipitated countries like Chile with 3000 mm precipitation factor.

Even though it was considered as sacred food during Inca civilization, its usage is reduced during Spanish colonial period where they considered quinoa as non- Christian but at the same time cultivation among local regions which gave path for localization of quinoa with various nutrient-values and also different visual aspects [4].

The annual quinoa consumption in Bolivia and Peru was 2.37 kg per person and 1.15kg per person while consumption in the United States was 0.03 kg per person. Quinoa flour is used to make a variety of toasted and baked goods including pizza, cookies, biscuits, noodles, pasta and pancakes. Quinoa seeds may also be fermented to produce beer or chicha, a popular South American ceremonial alcoholic beverage. Quinoa leaves are consumed like spinach while quinoa sprouts (germinated quinoa seedlings) are used in salads. The whole plant has also been used to feed animals such as goats, pigs, and chickens as it has rich nutritional components [5].

Production of quinoa: Quinoa is cultivated across 184,000 hectares, yielding an annual production of 161,000 tonnes, with Peru and Bolivia contributing to 99% of the total combined output [6].

The global production of quinoa has seen a significant rise, with the number of countries cultivating it growing from eight in 1980 to 40 in 2010, and further to 75 by 2014. This trend of increasing cultivation is evident in the data on quinoa's global expansion, its trends, and limitations. Additionally, in 2015, quinoa cultivation was introduced in 20 new countries. The United Nations General Assembly proclaimed ‘2013’ to be the **‘International Year of Quinoa (IYQ)’**. Quinoa has received a lot of attention as a crop with the potential to become more important in the field of agriculture. It is either grown or being tested in 95 countries around the world and global growth is expected to intensify as more countries experiment with the grain [7].

2. QUINOA PRODUCTION IN INDIA

Quinoa was introduced in India like other cereal grains which have been imported during green revolution but didn’t gain momentum like other grains. Quinoa research began in 1990 at the CSIR-NBRI in Lucknow as a means of reducing prevalent malnutrition in India. Because of the arid climate in the states, study was accelerated in 2000 and is now increasing in Rajasthan, Andhra Pradesh, Telangana and Karnataka. Because of the arid soil conditions in the Anathapuram district of Andhra Pradesh farmers primarily cultivate groundnuts. For the first time in India, the Andhra Pradesh government initiated Project Anantha in 2014, and quinoa seeds were distributed to farmers in the district for large-scale cultivation. A farmer in the Ananthapuram district harvested the crop successfully and 47 other farmers are growing it successfully. Quinoa is growing in the districts of Hyderabad and Ananthapuram. In Anantapur, a quinoa processing facility is being built to allow for the production of value-added goods [8].

Indian Medicinal Plants Marketing Federation launched a national programme named "Evaluation of Quinoa Development Capacity in Marginal Areas of the Indian Subcontinent" based on the excellent results obtained in the National Pilot Demonstration Program on October 2, 2009. Up to 2013-14, this initiative was in place for five years. Prior to the launch of this scheme the region under quinoa in India was almost non- existent, but by the end of it, it

Table 1. Year wise production of quinoa in India (2017-2018)

S.No	Year	Area (ha)	Production (Q)	Average Production (Q ha)
1	2009-10	46	483	10.5
2	2010-11	178	2047	11.5
3	2011-12	342	4412	12.9
4	2012-13	605	8954	14.8
5	2013-14	1165	18990	16.3
6	2014-15	3396	69958	20.6
7	2015-16	6278	134977	21.5
8	2016-17	7853	175122	22.3
9	2017-18	8630	206257	23.9

Table 2. State wide Quinoa production in India (2017-2018)

S.no	State	Area (ha)	Production (Q)	Average Production (Q ha)
1	Andhra Pradesh	1250	32250	25.8
2	Haryana	160	4416	27.6
3	Himachal Pradesh	480	9696	20.2
4	Madhya Pradesh	375	8775	23.4
5	Maharashtra	660	17952	27.2
6	Rajasthan	1585	35821	22.6
7	Tamilnadu	340	9146	26.9
8	Uttar Pradesh	910	21749	23.9
9	Uttarakhand	230	4899	21.3
10	Other states	2640	61553	23.3
	Total	**8630**	**206257**	**23.9**

had grown to 1165 hectares with a total production of 18990 quintals. In India, quinoa cultivation covers 8630 hectares with a cumulative yield of 206257 quintals (2017-18). In India, the average productivity of quinoa is currently 23.2 Q ha [9].

Rajasthan, Andhra Pradesh, Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh, Uttarakhand and Madhya Pradesh are the major quinoa-producing states in India at the moment.

In order to promote quinoa in Uttarakhand, the state signed a Horticulture Research Agreement with Peru in 2013. Quinoa is grown primarily in the

Jalor, Chittorgarh, Bhilwara, Jodhpur and Dungarpur- **Rajasthan**.
Fatehpur, Allahabad, Kanpur, Varanasi, Bundelkhand - **Uttar Pradesh**.
Faridabad, Rewani, Hisar, Bhiwani - **Haryana**.
Mandsor, Ratlam – **Madhya Pradesh**.
Ahmednagar, Beed, Solapur, Aurangabad, Jalna, Sangli, Pune - **Maharashtra**

Quinoa production is expanding across the world as a result of increased demand and its extraordinary adaptability to harsh environmental conditions. Quinoa is now cultivated in over 95 countries, according to 2017 estimates [9].

3. ROLE OF QUINOA IN FOOD SECURITY

In the twenty-first century, quinoa may be the key to addressing both food security and health. Its high nutritional value, well-balanced amino acid profile, adaptability to climate change and resilience to drought and salinity make it a prime candidate for future staple food, especially for the world's poorest populations [9].

India, due to its reliance on a limited variety of cereals, leads in malnutrition rates with over 45 percent of children, 70 percent of pregnant women, and nearly 52 percent of the populace suffering from diabetes. Quinoa, a high-protein grain could lessen the environmental impact of global food production, support dietary diversification and offer a chance to create innovative plant-based alternatives to meat, thereby reducing the demand for meat which adversely affects the environment. Plant proteins offer a sustainable option for reducing environmental damage. Food security could be bolstered by cultivating resilient crops like quinoa, which thrive under extreme conditions, have a strong nutritional profile, and are cost-effective to produce [10].

3.1 Composition of Quinoa

Investigation of the the total antioxidant capacity, total phenolic content and total anthocyanin contents in quinoa seeds and sprouts and found that quinoa seeds have a high antioxidant capacity (4.97) when estimated using FRAP and also when estimated using the ABTS method (27.22). The TAC value by the DPPH method was also found higher in quinoa seeds (38.84 ± 1.63) than amaranth seeds. The total phenolic components of quinoa were (3.75 ± 0.05), which was higher. The anthocyanin contents (120.4 ± 7.2) and concluded that quinoa seeds have higher antioxidant activity than other traditional food grains where quinoa can be used as a substitute for them [9].

The Quinoa seeds consist of 14.5g of protein, 5.2g of fat, 64.2g of carbohydrates,14.2 g of dietary fibre, 2.7g of ash, 32.9 mg of calcium, 206.8 mg of magnesium and 1.8 mg of zinc and 5.5 mg of iron in 100g of quinoa seeds on dry weight basis [10]. Quinoa and their products are high in both macronutrients like protein, polysaccharide, fats as well as micronutrients like polyphenols, vitamins, and minerals. Polyphenols, which include phenolic acids, flavonoids and tannins are bioactive secondary plant metabolites of antimicrobial, antioxidant, anti-inflammatory, antitumor and anti-carcinogenic properties [11].

According to the FAO (2011), the fundamental amino acid profile of quinoa is similar to that of casein and dried whole milk. Lysine, a limiting amino acid in cereal grains, is found in quinoa at double the concentration present in wheat or maize. Quinoa and amaranth are referred to as gluten-free grains due to their negligible prolamin content [12].

The ‘saponins’, natural detergents found in plants, are abundant in quinoa. They're found all over the plant, but they're more concentrated in the seed coat. Saponins have insecticidal, antibiotic, fungicidal, and pharmacological properties, which help the plant fight pests and pathogens on seven levels. These anti-nutritional compounds have bitter taste, but there are some “sweet” quinoa varieties without or with less saponin, saponins are a wide group of glycosides found in plants, and their name comes from the Saponaria genus [13].

Experiments on quinoa by extracting the leachate from the Quinoa seeds when treated with 70% ethanol, hypochloric acid, and incubation in sterile distilled water and reported the almost all of the 20HE in the seeds (491 g/g seed) was released during the leaching operation. The optimized quinoa leachate (QL), which contains 0.86 percent 20HE, 1.00 percent total phytoecdysteroids, 2.59 percent flavonoid glycosides, 11.9 percent oil, and 20.4 percent protein, contains 0.86 percent 20HE, 1.00 percent total phytoecdysteroids, 2.59 percent flavonoid glycosides, 11.9 percent oil and 20.4 percent protein [14].

Protein content present in quinoa ranges between 12.9%-16.5% which is higher than other cereals and the protein quantity and quality of quinoa are generally superior to those of cereal grains, while offering gluten-free property and high digestibility [15].

The study examined the composition of fatty acids, tocopherols, tocotrienols, and carotenoids in the seeds of three differently colored quinoa cultivars (white, red, and black), along with their antioxidant activity contributions. The concentrations of major components and individual compounds were significantly higher in the darker cultivars. Oil yields ranged from 6.58 to 7.17 percent, with unsaturated fatty acids constituting the majority (89.42 percent). The ratio of omega-6 to omega-3 fatty acids was 6:1. γ-tocopherol constituted the bulk of the tocopherol content, which varied between 37.49 to 59.82 mg/g. Trace amounts of β-tocotrienols were also detected. The highest levels of vitamin E were found in black quinoa, followed by red and white varieties. Notably, carotenoids like trans-lutein (84.7-85.6 percent) and zeaxanthin were identified in quinoa seeds for the first time, with the highest concentrations in black seeds. A strong correlation was observed between polyunsaturated fatty acids, total carotenoids, and total tocopherols with the antioxidant activities of the lipophilic extracts [16].

The proximate composition of unroasted quinoa seeds flour by soaking them in cold water for 4 hrs and then dried for 24 hrs. The proximate composition found in the flour was higher in Protein (16.32%), Ash (3.49%) and lower in Fibre (4.61) and crude fat (5.64%) [17] which is similar to the nutritive value of 100g quinoa consists of protein (13.11g), fat (5.50g), carbohydrates (53.65g), Energy (1367 Kj), Thiamine (0.83mg), Niacin (1.70mg), Riboflavin (0.22mg), Pantothenic Acid (0.62mg), Pyridoxine (0.21mg), Calcium (198mg), Iron (7.51mg), β-carotene (5.12µg). Quinoa contained total dietary fiber content of 14.66g consisting of 10.21 g of insoluble fiber and 4.46g soluble fiber [18].

On a dry weight basis, the saponin content in the seeds of both *C. album* and *C. quinoa* varied from 0.4 to 5.6 percent, with an average saponin value of 2.2 percent. Tannin content varied from 115 to 220 mg/100g, with *C. quinoa* having the highest level [19].

Quinoa protein is low in polyamines (0.5-7.0%), which indicates that it is free of gluten, therefore non allergenic. Quinoa contains 4.4-8.8 percent crude fat, with essential fatty acids linoleic and linolenic acid accounting for 55 to 63 percent of the total fatty acids and has lipid lowering effect [20].

The distribution of the nutrients and proteins in the Quinoa seed after applying abrasive milling for 8 minutes with 1 minute interval and reported that Quinoa seeds which were obtained after polishing from inverse milling trails consists of 13.18% of moisture, 8.59% of fat, 2.36% of Ash and 75.88% of carbohydrates and also reported that protein content has been decreased with increase in the milling where the protein content decreased from 13.57g to 5.00g by increase in each minute of milling but carbohydrates content was stabilized by increase in the milling [21].

Quinoa seed has a carbohydrate quality comparable to wheat and rice. Starch is the more present in quinoa, accounting for 32 percent to 69 percent of the total. Quinoa has a total dietary fibre content of 7.0–11.7 g/100g edible matter, similar to cereals like wheat and a soluble fibre content of 1.3–6.1 g/100g edible matter. Individual sugars make up 3% of quinoa seeds i.e., mainly maltose, D-galactose and D-ribose as well as low fructose and glucose levels [22].

A distinctive feature of quinoa is its balanced composition of essential amino acids. All essential amino acids were found to be present in quinoa, and the amino acid pattern is close to the requirements. Specifically, quinoa proteins are high in lysine (4.8g/100g protein) and threonine (3.7g/100g protein), which are generally the limiting amino acids in conventional cereals [23].

Quinoa protein has a high biological value at 73% which is comparable to beef at 74%, and higher than wheat at 49% and corn at 36%. In quinoa, the primary proteins are albumins (35%) and globulins (37%), with prolamins present in minimal amounts. The green leaves of quinoa contain high levels of lysine (1.9g), methionine (0.6g), and threonine (1.5g per 100g of protein), which are the amino acids often lacking in traditional cereals like wheat and maize [24].

3.2 Product Development

Dark chocolate was developed by incorporating 20% quinoa showed vitamin E increase by 9% and amino acids including cysteine, tyrosine, and methionine by 70-104 %. The sensory panel gave it a 70 percent approval rating [25].

Quinoa bread and flaxseed bread had a comparable texture and firmness, but quinoa bread received a higher level of market approval. Quinoa bread had a lighter crust and was less crumby, while flaxseed bread had a yellower crust and was crumbier [26] where as 20% quinoa flour substitution in their breads, gave them the same dough production time and consistency as wheat dough. The amount of the bread was 6.3 ml/g, which was smaller than wheat bread's 6.7 ml/g and protein content improved by 2.0 degrees [27].

The malt made with oats and quinoa can be considered as gluten-free product formulation. The amylase activity of the oats increases by 0.3 to 48 U/g as they germinate. The proteolytic activity was reduced by 9.6 to 6.9 U/g when Quinoa malt was added. While there were few variations in quinoa, the proteolytic enzyme activity declined from 9.6 to 6.9 U/g. The addition of oat malt to the batter reduces the viscosity of the batter during both heating and proofing. The improvements described above resulted in more open pores in bread and a decline in bread density from 0.59 to 0.5 g/ml. Due to low amylase activity, oat malt in excess induces excessive amylolysis during the baking process. Quinoa malt has little impact on the baking properties of the gluten-free products and other properties [28].

Gluten-free cookies using rice and quinoa flour in proportions of 15, 26, and 36% quinoa flour. According to 80 non-trained customer panelists, the formulation of 36.0 percent quinoa flour had the best α-linolenic acid and mineral content as well as outstanding sensory characteristics [29]. Gluten-free quinoa cookies with 30% quinoa flour, 25% quinoa chips and 45 percent corn starch were produced in another report. In comparison to the control batch, these cookies were high in essential amino acids, linolenic acid, minerals and dietary fibre [30]

The gluten-free bread enriched with green ‘mussel and protein hydrolysates (GMPH). Buckwheat flour (BWF), rice flour (RF), and chickpea flour (CPF) (10: 20: 10) were used to make gluten-free (GF) bread and GMPH was added in the range of 0-20%. The GF bread and GMPH elicited a stronger answer to sensors P 30/2, T 3O/1 and T 70/2 radio part of electric nose analysis. OMPH was discovered to be beneficial to celiac patients and offer health benefits [31].

Gluten free cereal bar using quinoa as major ingredient and using brown rice, flax seeds and dry fruits and honey at optimized levels for different formulations and studies physico-chemical properties of raw materials before and after heat treatment and evaluated organoleptic quality and shelf life of cereal bar reported that significant variation was found after treatment of grains among all the physico-chemical and functional parameters of grains except ash content which showed a non-significant variation. On the basis of sensory evaluation, formulation-4 at 50% honey level was found to be best. Selected cereal bar had 8.53% moisture content, 1.34% ash content, 10.50% protein content, 2.89% fat content, 0.51mg GAE/g total phenolic content, 33.87%antioxidant activity and 0.384 lg/g β- carotene [32]. Cookies, cakes, muffins, pies and tarts made with supplementation of quinoa flour were found to have higher protein, fat, calcium, iron, magnesium, zinc, tryptophan, methionine and lysine as compared to their control samples. Incorporation of quinoa flour above 10% causes the colour of product to become darker and bitter due to presence of saponins in quinoa [33]. Quinoa seeds flour biscuits made with 50 percent quinoa seeds flour or 75 percent rice and found that overall acceptability was not significantly different (Ps 0. 05) from that of control biscuits. Physical properties of biscuits made from various blends of rice and quinoa flours such as volume, weight, diameter and thickness also revealed that as the amount of quinoa flour rose, the volume of biscuits decreased steadily [34]. Chemical examination and caloric values of biscuits made from various blends of rice flour and quinoa flour. On the other hand the protein, sugar, and ash content of flour-replaced biscuits were found to be higher than the control biscuits.

Quinoa incorporated breakfast items such as chapati, kichadi, vada and reported that among the three breakfast items prepared, kichadi had the best sensory scores for colour, texture, taste, flavour and overall acceptability. The nutritive value analysis also showed that kichadi only had good mineral, protein and energy content amongst the breakfast items as the mineral content ranged between 2.05 to 4.96 g/100g. Protein between 8.87 to 13.47 g/100g, carbohydrate between 45.36 to 88.11 g/100g and energy from 383.25 to 487.96 K. Cal/100g with the descending order as followed: vada > kichadi > chapati. However, the values for crude fibre were followed as: chapati > vada > kichadi and values ranged between 2.59 to 4.23 g/100 and the values for fat were followed as: vada >kichadi> chapati and values ranged between 2.81 to 21.72 g/100 [35]. Snack items with incorporation of fermented quinoa flour by replacing major cereals and millet in the different proportions and developed products such as foxtail laddu, guntapunugulu and murukulu (crispy rice snack) and reported that that acceptability of snack items such as foxtail laddu, murukulu and guntapunugulu were organoleptically like moderately [36].

Lady finger biscuits (Italian) made with substitution of rice flour by quinoa flour and reported that all quinoa-based formulations positively affected the crust colour, giving the biscuits a more appealing crust colour. Biscuits with higher percentages of quinoa flour also had better structure, as they were softer. The substitution of Rice Flour with Quinoa Flour significantly improved the nutritional profile of the biscuits, as a result of the increase in protein, lipid, ash, total soluble (SP) and insoluble polyphenol (IP), flavonoid, and antioxidant activity levels, which increased linearly with the substitution rate. Sensory analysis revealed that the maximal substitution rate of QF able to maintain an adequate consumer acceptability rating is probably 50%, as higher percentages impaired acceptability due to the bitter taste [37].

3.3 Health Benefits of Quinoa Incorporated Products

An experimental study on 22 people aged 18-45 years fed with quinoa bars (10.5g/day) for 30 days and found that there was a significant reduction in various bio-chemical parameters with 67.5% of subjects reducing LDL cholesterol, 56.7% reducing blood glucose, 42.2% reducing hypertension and 40.7% reducing body weight. It was determined that making cereal bar with quinoa can aid in the regulation of risk factors associated with cardio-vascular diseases [38] while experiments on rats using leachate extracted from quinoa seeds using 70% ethanol, hypochloric acid and sterilized distilled water and reported that obese hyperglycemic rats had their fasting blood glucose levels considerably reduced. Leaching efficiently releases and concentrates bioactive phytochemicals from quinoa seeds, allowing for the production of a food-grade combination with anti-diabetic potential [39].

Quinoa's secondary metabolites can also lead to the preservation of human health and wellbeing, despite the fact that much of the emphasis on its health benefits has focused on its macro- and micronutrient profiles [40]. The saponins from bitter quinoa may be used in the pharmaceutical industry since saponins may trigger changes in intestinal permeability which may be beneficial for the absorption of certain drugs and the symptoms of hypocholesterolemia. Saponin has a variety of pharmacological properties, including the ability to act as an antibiotic and to regulate fungi [41].

Clinical experiments on rats revealed that eating quinoa on a daily basis reduced inflammation in the rat’s adipose tissues as well as the inner layer of their intestine. Saponins, which have anti-inflammatory properties, can be used as active ingredients in medicines. Quinoa saponin fractions blocked the release of inflammatory cytokines such as tumour necrosis factor-a and interleukin-6 in lipopolysaccharide-induced RAW264.7 cells murine macrophage cells and decreased the generation of inflammatory mediator nitric oxide (NO) caused by lipopolysaccharide (LPS). These findings support the use of quinoa saponins in the prevention and treatment of inflammation [42].

Dietary intervention study on 30 males and provided a control bread roll consists of refined flour and another bread roll with 20 % quinoa (16–25 g/day) was replaced with wheat flour and observed that there is change in LDL cholesterol. However, after 4 weeks of quinoa consumption, there was a significant decrease in glucose by 4.5% and LDL cholesterol by 5.7%

compared with the corresponding baseline, but the percentage change from baseline between the two treatments did not reach significance [43].

3.4 Effects of Processing on Quinoa

Baking significantly effects vitamin E content in quinoa and further increases with addition of quinoa, he addition of quinoa grains, which have the highest vitamin E content at 24.7 (measured in tocopherol equivalents), Among all tested loaves, the 100% quinoa bread exhibited the least reduction in vitamin E content (7.5%). This led researchers to conclude that incorporating quinoa in baking could yield gluten-free breads with enhanced vitamin E content [44].

Roasting and boiling influences the mineral composition and bioavailability *in vitro*, where quinoa seeds were roasted on a hot plate at 190℃ for 3 minutes and boiled for 20 minutes in tap water and proximates, calcium, zinc and iron dialyzability were determined. The results showed that calcium levels were lower in boiled and roasted grains, but their digestibility was higher, whereas iron and zinc levels were higher in roasted grains compared to raw and boiled grains, but their digestibility was higher during boiling, leading to the conclusion that including quinoa in the diet can increase mineral intake [45].

The malting impacts the nutritional properties of beverages made quinoa. The beverages made from raw, soaked, germinated and malted quinoa seeds by adding xanthan gum and boiling for 20 minutes. The physicochemical properties were analyzed, revealing that the malted quinoa beverage has higher protein content (2.9g), total soluble solids (9.69%), viscosity (17%), and activities of ACE inhibition, α-glucosidase, and α-amylase than those made from raw and soaked seeds. Conversely, the beverage from germinated quinoa contains more ash (0.28g) and sugar (14.78g) compared to its raw and soaked counterparts. Quinoa beverages can be included in a diet for managing type 2 diabetes and hypertension as part of a suitable dietary control strategy. They offer added health benefits for hyperglycemia by providing a greater inhibitory effect on the α-glucosidase enzyme and a lesser inhibitory effect on the α-amylase enzyme [46,47].

4. CONCLUSION

Quinoa, a nutrient-rich pseudocereal, is vital for food security because of its high protein content, which encompasses all nine essential amino acids, thus qualifying it as a complete protein source. Both the leaves and grains of quinoa are deemed functional foods due to their substantial protein, dietary fiber, mineral content and essential bioactive compounds. Quinoa may contain antinutrient compounds, the levels of which can differ based on the specific part of the plant and may be reduced through thermal heating such as roasting and baking. It is abundant in fiber, vitamins, and minerals contributing to overall health and well-being. Additionally, its gluten-free nature and antioxidant qualities increase its desirability, aiding in digestive health and mitigating inflammation. Quinoa’s adaptability and nutritional benefits make it a promising crop for diverse agricultural landscapes, including India can provide food security

5. FUTURE PERSPECTIVE

While some research has provided the advantages of quinoa and its bioactive compounds, more studies are necessary for a safety of quinoa. Consequently, additional well-structured clinical trials are necessary to validate the health benefits of quinoa and its derivatives. The nutritional value of quinoa may vary in response to environmental conditions, the investigations in this section are limited and need detailed examination.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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