Review Article

Quinoa –A Comprehensive review

Abstract

Quinoa, a nutrient-dense pseudocereal, is highly pertinent to a healthy lifestyle. Given India's specific challenges, including starvation, nutritional imbalances, health issues in newborns and nursing mothers, and extreme weather events like droughts, quinoa has become a staple food for the inhabitants of this subcontinent. This review study investigates the origin, production, nutritional composition, health benefits of Chenopodium quinoa Willd. And effect of processing on quinoa and its suitability for the food security in India.

Key words

Quinoa, Pseudocereal, nutridense, gluten free

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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, 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 and quinoa in especially Bolivia, Peru, Ecuador, Argentina, andChile.

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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)].

Thus, annual quinoa consumption in Bolivia and Peru was 2.37 kg per person and 1.15kg per person, respectively, 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 a rich nutritious source. [(5)].

Production of Quinoa:

Quinoa is cultivated in 184 thousand hectares with annual production of 161 thousand tonnes, led by Peru and Bolivia with 99% of the total when combined[(6)].

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Data about the Global expansion of the Quinoa along with its trends and limits and stated that from eight countries in 1980 to 40 in 2010 and 75 in 2014, the number of countries developing the crop has steadily increased. In 2015, quinoa was sown for the first time in 20 more nations. 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. Quinoa is either grown or being tested in 95 countries around the world. Quinoa's global growth is expected to intensify as more countries experiment with the grain[(7)].

Quinoa production in India

Quinoa was introduced in India like other cereal grains which have

been imported during green revolution. This situation arose due to India's dependence on the agriculture, where it was practiced by more than half of the population. It wasdifficult to feed the rapidly expanding population, so India had to import some food grains from other countries. 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. He also mentioned that 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-addedgoods[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 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].

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

Rajasthan, Andhra Pradesh, Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh, Uttarakhand and Madhya Pradesh are the most important 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 districts of Jalor, Chittorgarh, Bhilwara, Jodhpur and Dungarpur in Rajasthan. Quinoa is grown primarily in the districts of Fatehpur, Allahabad, Kanpur, Varanasi, and Bundelkhand in Uttar Pradesh. Quinoa is only grown in the districts of Faridabad, Rewani, Hisar and Bhiwani in Haryana. Quinoa is cultivated in the districts of Mandsor and

Ratlam in Madhya Pradesh. Ahmednagar, Beed, Solapur, Aurangabad, Jalna, Sangli and Pune are the major districts in Maharashtra where quinoa is successfully cultivated. 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].

Role of Quinoa in Food Security

In the twenty-first century, the quinoa crop may be the magic bullet that solves both food and health protection. The high nutritious value, well-balanced amino acid content in the grains, wide adaptability to climate change and harsh conditions, drought, salinity and its strength as a staple food of the world's poorest people are the key reasons for its selection as a food for thefuture [9].

Due to an overdependence on a few cereal items, India ranks first in malnutrition, with over 45 percent of infants, 70 percent of pregnant women, and nearly 52 percent of the population suffering from diabetes (rice or wheat). Now, it is the best time to bring quinoa to India in order to address some of the health issues that the Indian population is facing[10].Quinoa aids in diet diversification and provides the opportunity to develop innovative plant-based food substitutes, thus reducing meat demand, which is harmful to the environment. Plant protein is a viable alternative for mitigating harmful environmental effects. Quinoa is a high-protein grain that has the potential to reduce the global food's environmental impact. Food security can be enhanced by growing crops like quinoa based on their ability to grow to sustain during extreme conditions and nutritional profile and also low production cost[8].

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 ABTSmethod

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(27.22). The TACvaluebytheDPPHmethodwasalsofoundhigherinquinoaseeds (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 forthem[9].

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The report of the nutritive value of quinoa of quinoa in both vitamins and minerals. 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].

FAO (2011) claims that the basic amino acid composition of quinoa is comparable to that of casein and dried whole milk. One of the limiting amino acids in cereal grains, lysine, is present at twice the amounts found in wheat or maize. Quinoa and amaranth are called gluten- free grains because they have very little to no prolamin [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 20.4percent 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 was quite high i.e. 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]. Avenin polypeptides in oats are rich in proline and glutamine, close to other cereal prolamins and protein regions enriched in these two amino acids are linked to celiac disease elicitation. As compared to prolamins found in other cereal grains, oat prolamins have the following molecular size, percentage, and amino acid content differences. Prolamins make up 10-20% of the total protein in oats, while they make up 40-50% of the total protein in wheat. Among the approved prolamins, those present in maize, sorghum, and pleasant have the lowest proline and glutamine contents (25-30%), while prolamines in the triticeae tribe (wheat, barley and rye) may have proline and glutamine contents exceeding 70% of total amino acids. Proline and glutamine, on the other hand, make up 35-50 percent of the amino acids present in the prolamins ofoats[16].

The investigation of the composition of fatty acids, tocopherols, tocotrienols, and carotenoids in the seeds of three different coloured quinoa cultivars as well as their contribution to antioxidant activity (white, red and black). The concentrations of the major components and individual compounds were substantially higher in darker plants. The oil yield was 6.58-7.17 percent, with the majority of the fatty acids being unsaturated (89.42 percent). The omega-6/omega-3 fatty acid ratio was 6/1. γ-tocopherol made up the majority of the overall tocopherol material, which ranged from 37.49 to 59.82 g/g. There was also a trace amount of and β-tocotrienols detected. The largest amount of vitamin E was found in black quinoa, supplemented by red and white quinoas. For the first time, carotenoids such as trans-lutein (84.7-85.6 percent) and zeaxanthin were

found in quinoa seeds, with the largest concentration in black seeds. Polyunsaturated fatty acids, total carotenoids and total tocopherols were all shown to be strongly associated with the antioxidant activities of lipophilic extracts[17].Theproximate 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%)[18] 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 solublefiber[19]. 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[20].

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[21].

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[22].

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 dietaryfibre 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 [(23)].

Product development

Darkchocolate was developed by incorporating 20% quinoa that increased vitamin E by 9% and amino acids including cysteine, tyrosine, and methionine by 70-104 %. The sensory panel gave it a 70 percent approval rating[(24)].

Quinoa and flaxseed breadhad 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[(25)] 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. Quinoa bread's protein content improved by 2.0 degrees[(26)].

The addition of oats and quinoa malt to the 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 to6.9 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. The conclusion was that malt-induced proteolysis had little effect on the gluten-free products other properties[(27)].

Gluten-free cookies using rice and quinoa flour in proportions of 15, 26, and 36% quinoa flour. According to 80 non-trained customer

panelists, theformulation of 36.0 percent quinoa flour had the best α-linolenic acid and mineral content, as well as outstanding sensorycharacteristics[28].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[29]

The gluten-free breadenriched 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 healthbenefits[30].

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[31]. 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[32]. 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 ofcontrol 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[33]. Chemical examination and caloric values of biscuits made from various blends of rice flour and quinoa flour. On the other hand, revealed that the protein, sugar, and ash content of flour-replaced biscuits were higher than the control biscuits.

Quinoa incorporated breakfastitems 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[34].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[35].

Lady finger biscuits (Italian) 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

consumeracceptability rating is probably 50%, as higher percentages impaired acceptability due to the bitter taste[36].

Health benefits of Quinoa incorporatedproducts

An experimental study on 22 people aged18- 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-vasculardiseases[37] 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[38].

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[39].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 regulatefungi[40].

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

ofinflammatorymediator nitric oxide (NO) caused by lipopolysaccharide (LPS). These findings support the use of quinoa saponins in the prevention and treatment of inflammation[41].

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[42].

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Effects of processing onquinoa

Baking ofquinoa impacted the vitamin E content of quinoa varied slightly on with addition of quinoa grains having the greatest vitamin E content i.e.,, 24.7 (measured in - tocopherol equivalents). The 100 percent quinoa bread had the least amount of losses out of all breads evaluated (7.5 percent) and concluded that quinoa as a gluten-free baking ingredient, it produces gluten-free breads with higher vitamin E content[43]. 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[44].

Malting of quinoa has impact on the beverages made with raw, soaked, germinated and malted quinoa seeds were prepared by adding xanthan gum and boiling for 20 minutes and physiochemical properties were analyzed. The malted quinoa beverage contains more protein (2.9g), TSS (9.69%), viscosity (17%), and ACE inhibition activity, α-glucosidase activity, and α-amylase inhibition activity than the raw and soaked

beverages, whereas thegerminatedquinoabeveragecontainsmoreash(0.28g) and sugar (14.78g) than the raw and soaked beverages and implicated that Quinoa drinks may be incorporated into a type 2 diabetes and hypertension diet as part of an appropriate dietary control plan. An additional value to the health potential due to hyperglycemia is a higher inhibitory potential against α-glucosidase enzyme and a lower inhibitory potential against α-amylase enzyme[45].

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. It is abundant in fiber, vitamins, and minerals contributing to overall health and well-being. Additionally, its gluten-free attribute 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.

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