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Nutritional Profile and Health Benefits of Buckwheat: A Miracle Pseudo Cereal

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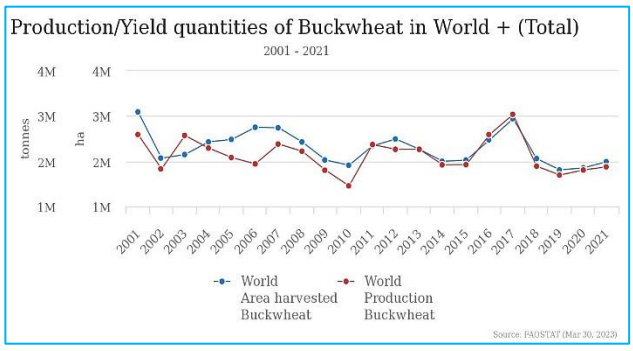
Abstract

Among the pseudocereals, buckwheat is a gluten-free underutilized short duration crop under the family Polygonaceae. Countries that grow buckwheat are China, Russia, Japan, France, Brazil, Poland, Kazakhstan, United States of America, and in India it is cultivated in North Western and Eastern Hills and some parts of southern India. Buckwheat has attracted the interest of consumers due to its nutritional properties, grains are rich in protein with balanced amino-acid composition, fiber, vitamins, resistant starch, and bioactive compounds (flavonoids, rutin, phenolic acids, quercetin). These bioactive compounds help in the prevention of chronic diseases. Grains of buckwheat are gluten-free, so many food recipes are formulated for celiac patients.

***Key words*:** Buckwheat, Nutrient profile, Bioactive compounds, Health benefits, Value addition

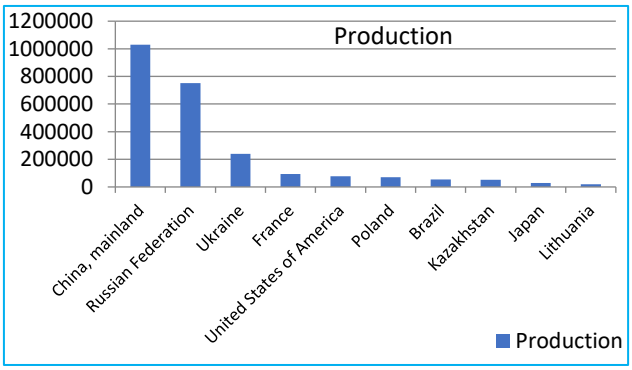
Cereals have been known as the staple food of most population since ancient time they include; rice, maize, and wheat, which are monocots and belong to the family Poaceae, but amaranths, quinoa, buckwheat, and chia although resembles cereals are dicots and are known as pseudo-cereals as these seeds are similar to cereals in their functions and composition and are lenticular in shape [1]. These pseudo-cereals are underutilized crops due to their less yield production, awareness, and processing of seeds [2] but these are considered starchy food grains and have received appreciation from consumers and nutritionists due to their nutritional value and health benefits and the grains like buckwheat, quinoa is cultivated in India since many years [3].



Source: FAOSTAT, 2023

Fig 1 Production of Buckwheat in the world from 2001-2021

On a global basis, pseudo cereals are regarded as a minor crop. Moreover, many pseudo cereals can thrive in poor soils as well as in conditions that other grain species cannot. The three primary pseudo-cereal crops are buckwheat (*Fagopyrum esculentum*; Polygonaceae), quinoa (*Chenopodium quinoa* subsp. quinoa; Chenopodiaceae), and amaranth (*Amaranthus caudatus*; *A. cruentus*; *A. hypochondriacus*; family: Amaranthceae). The production of these grains is increased due to their nutritional profile and health benefits [4].



Source: FAOSTAT, 2023

Fig 2 Top 10 producers of Buckwheat in the world

Buckwheat cultivation widened from the south to the north of China, then to the countries of Korea and Japan, as well as from Tibet to Bhutan through China, Nepal, India, and Poland. According to FAO [5] data analysis, the total buckwheat yield is 3,827,748t harvested on 3,940,526hm2 of farmland. China generated the highest quality buckwheat (1,683,615hm2), followed by Russia (15,524,280t), Ukraine, France, the United States, Poland, Brazil, Kazakhstan, Japan, and Lithuania. Buckwheat is grown in the high mountains of Jammu and Kashmir, along with Ladakh, Himachal Pradesh, Uttarakhand, West Bengal, Sikkim, Meghalaya, Arunachal

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Pradesh, Manipur, and the NiLgris and Palni hills of southern India [6]. Buckwheat can grow in adverse environmental conditions, as a small season crop from 70-90 days [7] and can grow mostly in hilly areas because of its frost tolerance levels [8].

Buckwheat is the staple crop of the Indian Himalayan people which belongs to the family Polygonaceae [2], two species of buckwheat are grown in India, they are Mithey/common buckwheat (*Fagopyrum esculentum*) and Tartary buckwheat (*Fagopyrum tataricum*), and these are mainly cultivated in the higher altitudes of up to 4500m [9-10]. Buckwheat is similar to amaranth and quinoa but is not related to wheat, the seeds of buckwheat are triangular with gray-brown or brown-black in color, and contain a thick hull (pericarp) which covers the seed's coat, endosperm, and embryo [4]. The seeds of buckwheat are an excellent protein supplier with a balanced composition of amino acids and are packed with fiber, minerals, flavonoids, and phenolic substances [7].

Table 1 Sowing time of buckwheat in India

Region	Sowing time
North-Western hills	June-July
	March-April
North-Eastern hills	August- September
Sikkim	October-November
Nilgiri Hills (Tamil Nadu)	April-May
Plani Hills (Tamil Nadu) and Kerala	January
Chattisgarh	September-November

Source: Chrungoo *et al.* [7]

In recent years the pseudo-cereal buckwheat has been receiving great interest from consumers and has been developed as new functional food rich in zinc (Zn), copper (Cu), manganese (Mn), potassium (K), and magnesium (Mg), and its vitamin profile contains high vitamin B group especially vitamin B1, B2, B3, and B6 is also gluten-free suitable for individuals having celiac disease [3].

Source: Ruan *et al.* [11]

Fig 3 Morphological characteristic of *Fagopyrum tataricum*.
A- Lower parts of the plant B- upper part of the plant,
1- flower, 2- grains, 3- pistil, 4- ovary, 5- seed, 6- seed cross-section

Nutrient profile

Carbohydrate

Carbohydrate is the major component of the nutritive profile containing 68-73% of which starch is around 54-55% and it contains higher amylose content (18.4 – 47% of total starch) when compared to quinoa and amaranth, which causes a medium rise of the glycemic index. The amylose is lightly branched and amylopectins are present in form of long chains affecting the process of gelatinization, and causing an increase in the viscosity of starch [12]. Resistant starch cannot be digested easily and is absorbed from the gut and provides greater health benefits, the amount of resistant starch in buckwheat is 27-33.5% [13] and it contains higher dietary fiber (17.8%), composed of lignin (6.9%), cellulose (10.64%) and hemicelluloses (2.22%) [14].

Proteins

The content of protein in buckwheat is 5.7- 14.2% [15] containing different amounts for specific species, and albumin, globulin, and glutelin are the major fractions making the bran flour have higher protein content. As known, the key factor for determining protein quality is amino acid composition, when studied the protein content of buckwheat is lower than legumes but the amino acid profile was higher stating the high quality of protein [16]. The seeds contain 12-15% protein which is 5.9% lysine and 2.3% methionine and have lower ratios of methionine to glycine and lysine to arginine [7].

Buckwheat protein is utilized as a raw ingredient to generate bioactive peptides due to its molecular composition of protein. The crude protein content of buckwheat is increased by 7% by the process of germination for 72 hours because the rate of protein is higher than the rate of degradation. Through the process of solid-state fermentation with Rhizopus oligosporus, the digestibility of buckwheat protein increased from 39.9% to 55.6% [16].

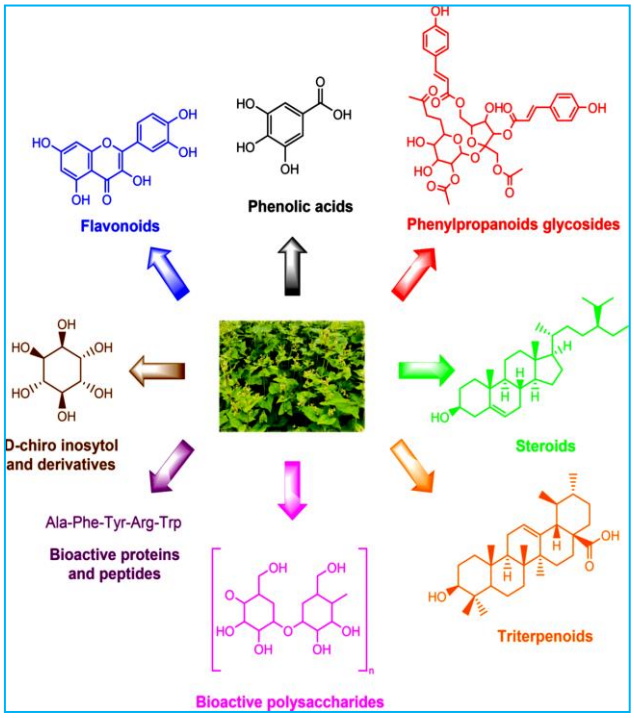
Lipids

The Tartary buckwheat contains 2.5% lipids and the common buckwheat contains 3.4% of lipids and the amount of unsaturated fatty acids is higher in common buckwheat than Tartary buckwheat species. Buckwheat contains six fatty acids palmitic (C16:0), oleic (C18:1), linolenic (C18:2), linolenic (C18:3), stearic (C18:0) and gondoic (C20:1) found in all varieties [17] and palmitic acid is the main saturated fatty acid and the seeds contain oleic and linoleic acid mostly [18]. The embryo contains higher lipids which are unsaturated fats (7 to 14%) and the hull contains the lowest lipids which are saturated fatty acids (0.4 to 0.9%) [19]. The lipid content in seed ranged from 9.6% to 19.7% [20] buckwheat oil contains 16-25% of saturated fatty acids and 74.79% of unsaturated fatty acids [21].

Vitamins and minerals

Buckwheat grains and its products have an adequate level of minerals in them based on the type of milling process done and the least levels are in fine flour of buckwheat. Buckwheat is rich in calcium, iron, magnesium, potassium, zinc, chromium, and cobalt in comparison to all cereals [22]. The amount of trace elements present in buckwheat grains is calcium (110mg/100g), iron(4mg/100gm), magnesium (390mg/100g), phosphorous (33mg/100g), and potassium (450mg/100g) [2]. Tartary buckwheat has a higher amount of organic selenium, which forms a "metal-selenium-protein complex" in the body which helps in the elimination of toxic elements from the body and it also contains trivalent chromium which enhances glucose tolerance levels in the human body. The content of vitamin B in kernels of buckwheat is 0.78mg/100g and the amount of vitamin E is 9.5mg/kg [11]. Buckwheat contains vitamin B1 (Thiamine), B3 (Niacin), B6 (Pyridoxine), vitamin K, and vitamin E as tocopherol (117.8

g/g). The germination process boosted vitamin B1 and C content. Buckwheat flour is rich in vitamin B compared to rice flour, and Tartary buckwheat contains more vitamin B concentration while common Tartary contains more vitamin K concentration [22].



Source: Zou *et al.* [23]

Fig 4 Structure of bioactive compounds isolated from Buckwheat

Table 2 Nutritional composition of Buckwheat

S. No.	Nutritional value per 100g	
	Proximate composition	
1	Energy	355 k.cal
2	Carbohydrate	72.9g
3	Protein	12g
4	Fat	7.4g
5	Dietary fiber	17.8g
	Minerals	
6	Calcium	110mg
7	Iron	4mg
8	Magnesium	390mg
9	Phosphorus	330mg
10	Zinc	0.8mg
11	Potassium	450mg
	Vitamins	
12	Thiamine	3.3mg
13	Riboflavin	10.6mg
14	Niacin	18.0mg
15	Pantothenic acid	11.0mg
	Essential amino acids (% of total protein)	
16	Lysine	5.9%
17	Methionine	3.7%
18	Tryptophan	1.4%
19	Leucine	6.7%

Source: Chrungoo *et al.* [7], Pirzadah and Malik [2], Huda *et al.* [22]

Bioactive compounds

Several flavonols are found in Tartary buckwheat as rutin, quercetin, kaempferol derivatives, and rutin is found to be most abundant around 90% of phenolics, the content of rutin is 110mg/100g of fresh weight [23] and rutin can prevent cerebral hemorrhage, pulmonary hemorrhage, gastric ulcers whereas quercetin helps in prevention of blood clotting [11]. The method of processing affects the rutin and phenolic content in the buckwheat grains as syringic acid, ferulic acid, and 4-hydroxybenzoic acid concentrations but this can be enhanced by the fermentation process [23]. The main phenolic acid compound is hydroxybenzoic acid accounting for 58.6% and 78.82% of total phenol content in buckwheat bran and core powder and the amount of hydroxybenzoic is more in Tartary buckwheat than common buckwheat [11]. Anthocyanins are the compounds that impart color-producing pigments in flowers, fruits, and plants, there are 18 anthocyanins from which four anthocyanins – cyaniding 3-O-galactoside, cyaniding 3-O-rutinoside, cyaniding 3-O-galactoside, and cyaniding 3-O-galactopyranosyl-rhamnoside are found in the sprouted buckwheat which reduces the heart diseases. In sprouts, the anthocyanin is more in hypocotyls rather than in cotyledon [22]. Tannins are the phenolic compounds that protect humans from stress and its present in higher quantities in buckwheat brans, at the time of seedling the tannin content increases in buckwheat [24].

Health benefits

Buckwheat is a plant with great medicinal value, all parts of the plant are used significantly to cure various diseases as it contains various antioxidant compounds, and phenolic compounds (rutin, quercetin) [9].

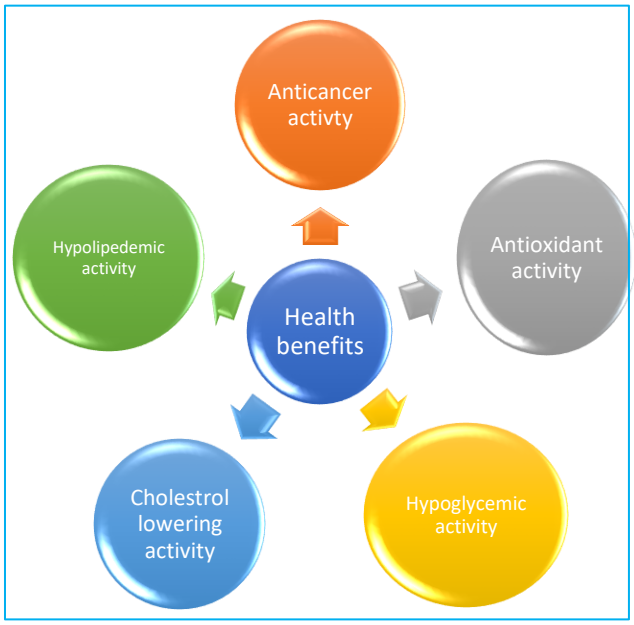


Fig 5 Health benefits of buckwheat

Cholesterol lowering activity

Zhang *et al.* [25] conducted a study on 45 male hamsters which are divided into 5 groups and fed with control diet and experimental diets (24% Tartary buckwheat,24% rice protein,24%wheat protein,5g kg^{-1} cholestyramine) it showed that buckwheat protein showed higher deduction of plasma total cholesterol than cholestyramine and the excretion of total neutral sterols was increased by 108% examine the capacity of plasma cholesterol lowering. Buckwheat protein shows its effect in lowering cholesterol by increasing the excretion of sterols from the body through fecal matter. The studies conducted in vitro condition showed that 83% of cholesterol is bound directly to poorly digested buckwheat protein and it's excreted by fecal excretion leading to a decrease in cholesterol which is absorbed into intestinal layers [16]. Magnesium regulates myocardial activity; the magnesium in buckwheat is 11 times greater than in wheat flour. The powder of buckwheat

is vitamin-rich and helps in lowering blood lipid and cholesterol levels and it is used to cure hypertension and cardiovascular diseases [11].

Anti-cancer activity

The flavonoids present in buckwheat show their efficiency in lowering mammary carcinogenesis by reducing the levels of serum estradiol and they also reduce colon cancer by decreasing the activity, and proliferation of cells. Buckwheat is the only source of rutin from edible parts and the highest quality is from leaves before flowering, these can be used for fortification of food and making it rutin rich. Quercetin is a bioactive compound present in buckwheat that can decrease the growth of cancer cells by lowering the expression of oncogenes, and inhibition of angiogenesis [9].

Hypoglycemic effect

Ruan *et al*. [11] conducted a study that showed that buckwheat can reduce glycosylated hemoglobin, glycosylated serum protein and reduce blood lipid levels leading to lowering the chances of developing diabetes. The rate of the cause of hyperglycemia was around 1.6% in the area where buckwheat is the main staple crop and was around 7.3% in the areas where buckwheat is not a staple food crop, the difference in the ratios suggests that buckwheat helps in lowering and prevention of hyperglycemia in human. The polysaccharides of buckwheat show anti-diabetic activity, as they decrease blood sugar levels by inhibiting alpha-glucosidase, and these polysaccharides further reduce the catalytic activity of pancreatic lipase which helps in controlling obesity [26].

Antioxidant effect

Natural product polysaccharides are a great source of bioactive and antioxidant substances. In vitro tests on buckwheat polysaccharides revealed enhanced enzyme function as these enzymes contribute to the defense of biomolecules against free radicals [26-27]. The buckwheat protein also showed antioxidant products with free radical scavenging when it is digested in vitro by using pepsin+ pancreatin [16].

Hypolipidemic activity

According to research done by Zou *et al*. [23] on mice, buckwheat's bioactive protein prevents dyslipidemia when mice are fed a high-fat diet, which results in lower levels of both total cholesterol and triglycerides. The fentanic acid and flavonoids present in buckwheat help in the removal of extra fat thus lowering the blood-lipid level and the flavonoids improve the levels of high-density lipoproteins. Polyphenols and proteins inhibit the hardening of blood vessels and anthocyanins reduce the deposition of lipid peroxides in the blood vessels, which further reduces the lipid levels in the blood and liver [11].

Value added products

As buckwheat is a gluten-free cereal food industry has shown significant importance in developing various gluten-free products for individuals suffering from gluten intolerance [4].

Buckwheat pasta

According to Bastida *et al*. [28] In recent times, several researchers have studied the influence of hydration level, buckwheat flour concentration, and drying temperature on the processing properties and physical and cooking attributes of gluten-free pasta. Using grounded buckwheat hull in place of semolina in amounts of 0, 1, 5, 10, 15, and 20%, Sujka *et al*. [29] prepared pasta, made the dough, and dried it at 55 °C until the moisture content was 11–12%. The research found that buckwheat can only be incorporated up to 10% beyond showed unpleasant smell and taste. The incorporation of buckwheat hull increased the fiber content (4.31% to 14.15%), total phenolic content, and antioxidant activity. However, it showed a decline in the color and brightness of pasta.

Buckwheat flour cakes

The functional food industry has identified buckwheat as a potential ingredient for composite flour-based bakery products such as cookies and cakes due to increasing consumer demand. A study was conducted by Farzana *et al*. [30] to analyze the nutrient composition and microbiological safety of buckwheat fortified cakes (BFC) compared to locally available branded cakes (LBC). BFC was prepared using varying concentrations of buckwheat flour and wheat flour, with 30% buckwheat flour resulting in the best quality and highest acceptability among skilled panelists. BFC also had higher protein, fat, fiber, and micronutrient content than LBC. Sensory tests did not reveal significant differences between BFC and LBC. Microbiologically, BFC was deemed acceptable for consumption for up to nine days. Overall, cakes prepared with 30% buckwheat flour are nutritionally superior to other cakes available in Bangladesh.

Soft *et al*. [31] prepared buckwheat eggless cake using whole buckwheat flour, which is known to be rich in protein, antioxidants, fiber, flavonoids, flavones, and phytosterols. To optimize the baking time and temperature for the development of the cake, Response Surface Methodology (RSM) was successfully used. The study evaluated the impact of baking time and temperature on five responses, including weight loss, moisture content, specific volume, hardness, and browning index. The baking temperature and time were varied from 140 °C to 160 °C and 50 to 70 minutes, respectively. The moisture content of the buckwheat cake decreased as the temperature increased, with values decreasing from 42.41± 0.35% (batter) to 27.13 ± 1.30%, 24.61 ± 0.50%, and 16.93 ± 0.28% at 140 °C, 150 ˚C, and 160 °C, respectively. The specific volume of the cake increased as the baking time and temperature increased from 1.98 ± 0.17cm, 3.g-1 to 2.35 ± 0.03 cm, $3.g^{-1}$. Weight loss, browning index, and hardness of the cake also increased significantly. Using a face-centered composite response surface design, the optimal time and temperature for baking the cake were found to be 156.82 °C for 63.01 minutes with desirability of 1.00.

Source: Shreeja *et al*. [32]

Fig 5 Idly prepared with buckwheat

Buckwheat idly

Shreeja *et al*. [32] study was to assess the viability of buckwheat flour that had been germinated for the creation of idly. Three recipes were created, substituting idly rava to varying degrees (25, 50, and 75%) with germinated buckwheat flour. The findings showed that 25% buckwheat flour was the most acceptable.

Buckwheat nutri ball

Nutriball was created by Gowmathi and Parameshwari, [33] using peanut and buckwheat flour in varying amounts (10g, 20g, 30g, and 40g). Research revealed that the 30g flour had the highest levels of protein (13.56±0.16), fiber (6.07`±0.13), total phenolic content (5.97±0.11), and antioxidant capacity (34.2±10.17) and was also the most palatable.

Source: Gowthami and Paramehswari [33]

Fig 6 Nutriball

Buckwheat bread

Coronel *et al*. [34] prepared the formulation of gluten-free bread, premixes based on buckwheat flour (light or whole grain) with the addition of chia flour (CF), xanthan gum (XG), or a combination of both were created. In comparison to the control bread made with a commercial premix, the gluten-free bread made with the selected premix (light buckwheat flour with the addition of chia flour and xanthan gum) had better nutritional qualities (higher protein and crude fiber content), higher antioxidant activity, and a significant amount of essential polyunsaturated fatty acids (linoleic and linolenic acids). This marks a promising application of partially deoiled flour, a by-product of the cold-pressed chia oil extraction process, as a functional ingredient in the production of gluten-free bread.

Source: Coronel *et al.* [34]

Fig 7 Buckwheat bread

Rozanska *et al*. [35] conducted a study to demonstrate the formation of Maillard reaction products in buckwheat bread made from raw and roasted flour. Making buckwheat bread affects the production of compounds that have antioxidant properties, but it also creates potentially harmful Maillard reaction products such as FUR, FIC, and CML. However, the study suggests that using raw buckwheat flour is better for making buckwheat bread because the use of roasted buckwheat flour results in a higher concentration of fluorescent intermediate compounds and the formation of advanced glycation products.

CONCLUSION

Buckwheat, the pseudo cereal is a crop with a short growing season and good surviving capabilities and its production is drastically increasing in India, due to its nutritive profile of well-balanced amino acid profile, dietary fiber, rutin content, and bioactive compounds (flavonoids, rutin, phenolic acids, quercetin). Flavonoid compounds in buckwheat help to prevent chronic diseases like anti-cancer activity, anti-oxidant activity, hypoglycemic activity, Cholesterol-lowering activity, and hypolipidemic activity. Buckwheat has huge scope in the food technology industries to develop new food products like gluten-free snacks, ready-to-eat breakfast cereals, bakery products, and neutraceutical products based on their properties.

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