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Buckwheat: An Advancing Crop for Future Generations

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Common buckwheat (Fagopyrum esculentum) stands as a versatile and widely cultivated crop with a rich history of utilization across the globe. Conversely, Tartary buckwheat (Fagopyrum tataricum) finds its primary niche in China, where it is cultivated and consumed. Both varieties contribute

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significantly to global agriculture, providing essential food items in the form of grains and flour. Common buckwheat, known for its adaptability, is often grown in diverse climates and geographical regions. It is raised in short seasons, making it a suitable candidate as a second crop, complementing other primary crops in a rotation system. Its adaptability and versatility have earned it the reputation of being one of the most reliable summer season crops. Beyond its nutritional contributions, buckwheat possesses a fundamental prophylactic property crucial for human health – antioxidant activity. This property gives rise to a variety of essential biological functions, including antimutagenic, anticarcinogenic, and antiaging effects. The antioxidant content in buckwheat makes it a valuable dietary inclusion, supporting overall well-being and disease prevention. Recent studies have delved into the molecular basis of buckwheat products, exploring their technological and textural characteristics. This research not only enhances our understanding of the composition and quality of buckwheat-based foods but also opens doors to broader applications in future generations. The knowledge gained from these studies may lead to the development of improved buckwheat varieties and innovative food products with enhanced nutritional profiles.

Keywords: Buckwheat; season crop; summer weeds; gluten-free product.

1. INTRODUCTION

"Buckwheat (*Fagopyrum esculentum)* is one of the most important green manure crop and semi-succulent dicot plant which belong to the genus *Fagopyrum* and the family Polygonaceae" [2]. "Hence its name. It Is a pseudocereal crop (seeds that are consumed in the same way cereal grains but are not grown on grasses and there are two cultivated species, i.e., common buckwheat (*Fagopyrum esculentum*) and Tartary buckwheat (*Fagopyrum tataricum).* Common buckwheat is most widely cultivated and utilized, while Tartary buckwheat is mainly grown and consumed in China. It is consumed in the form of groats and flour, which are used as food items. Raised in short season and as the second crop. Most reliable summer season crop. It establishes quickly, which suppresses summer weeds" [3].

"Buckwheat tea, known as memil-cha in Korea and soba-cha in Japan, is a tea made from roasted buckwheat" [4] . "Buckwheat is rich in protein of excellent quality as well as starch. In addition, it also contains high levels of fiber, minerals, vitamins, and flavonoids with positive therapeutic effects on the human body Buckwheat has increasingly attracted attention because of its positive effects on some chronic diseases conditions, such as hypertension, hypercholesterolemia, diabetes, and other cardiovascular diseases.it is also used as a functional food" [2].

"In India, it is called kuttu ka atta and is eaten in Navratris. It is a non-cereal flour commonly used for making parathas, and pakodas" [5]. "It is cultivated for its nutritious triangular seeds and is a cover crop. The grains are usually brown and irregular in shape. It's a completely gluten-free product. Buckwheat has been used as a substitute for other grains in gluten-free beer" [6]. "Buckwheat consumption is linked with several health benefits, including improved blood sugar control, hypertension, hypercholesterolemia, diabetes, and other cardiovascular diseases. It also has anti-inflammatory properties. It's a gluten-free crop and is safe for people with celiac disease. Roasted buckwheat groats, called kasha. Buckwheat has more protein than cereals. High amounts of essential amino acids lysine and arginine are present which are deficient in major crops. Its unique amino acid profile gives buckwheat the power to boost the protein value of beans and cereal grains eaten the same day which is a key advantageous feature for us. Buckwheat contains no gluten. Nevertheless, buckwheat may have gluten contamination" [7]. Buckwheat flower produces honey of good quality. Government schemes like National Food Security Mission has emerged as a crucial instrument in boosting food grain production and ensuring food availability for India's population [40]. Tahir et al. [8] studied that "Buckwheat can become an important crop in the feeding of mankind and domestic animals to meet the ever-increasing demands of a rapidly expanding population". It can prevent or reduce weed growth [9].

2. ORIGIN AND HISTORY

"The wild ancestor of common buckwheat is *F. esculentum ssp. ancestrale*. *F. homotropicum* is interfertile. Yunnan in china has a common distribution of *f.esculentum.* the wild ancestor of Tartary buckwheat is *F. tataricum ssp Potanini"* [10]. "The oldest remains found in China so far

date to circa 2600 BCE, while buckwheat pollen found in Japan dates from as early as 4000 BCE. Buckwheat was one of the earliest crops introduced by Europeans to North America" [11]. Also called beecGoverh wheat, which resembles the much larger seeds of the beech nut from the beech tree.

3. GEOGRAPHICAL DISTRIBUTION

"In 1993, history played a record in making Russia the largest producer of buckwheat. It is reported that in 1990, buckwheat yield per hectare reached 3400 kg in Russia. China has the longest history (since the seventh century AD) of buckwheat cultivation, and now ranks second in world production with an average annual cultivation area of 1.33Mha. Buckwheat grows mainly in the northern hemisphere, notably in Russia, China, Japan, India, Kazakhstan, China, Poland, Ukraine, Canada, and the USA. Buckwheat is also planted in the southern hemisphere, e.g., in Brazil, Australia, and South Africa" [2]. "Globally Russia is the leading producer of buckwheat. As of 2016, it remains a key cereal" [12].

Table 1. Producer of buckwheat [13]

Russia	1,186,333
China	404,259
Ukraine	176,430
France	122,206
Poland	118,562
Global production	2,395,822

"In India, the crop is widely cultivated in Jammu and Kashmir), Himachal Pradesh, Uttarakhand (Uttar Kashi, Chamoli, Pauri, Almora, and Pithoragarh), West Bengal, Sikkim, Meghalaya, etc. In South India, it is sporadically grown in the Nilgiris and Palni hills" [14].

Shah [15] studied "explored buckwheat in North West Jammu & Kashmir". Kump and Javornik, [16] report state that "it is grown as a minor grain crop in high-altitude areas in India. (1600-4000 m above mean sea level). It's cultivated in the hills of the states of Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, Manipur, and Arunachal Pradesh under low input conditions and gets exposed to harsh environments. Most important crop for the people of the Uttarakhand state. However, the productivity of buckwheat is quite low (4.5 q/ha) in Uttaranchal. Two species of buckwheat are prevalent in Uttaranchal viz., common buckwheat (*Fagopyrum esculentum, Moench*) locally called Ugal, and tartary buckwheat (*F. tataricum Gaertn.)* locally known as Phapar. VPKAS, Almora developed and released a variety of *F. esculentum (VL Ugal 7)* in 1991. However, this variety performs well only in mid-altitude areas (1000-1500 meters above mean sea level). About 800 years ago tartary buckwheat appeared suddenly on 47-60° northern latitude".

4. NUTRITIONAL VALUES

"The main storage protein of buckwheat grains is 13S globulin "[1]. Important microelements such as Zn, Cu, Mn, and Seare were found [17], and the major elements are potassium, sodium, calcium, and magnesium [18]. "The average albumin content is 21%, whereas the highest one reaches 30–33%" [19]. Mistunaga et al. (1986) first isolated "the thiamin-binding proteins (TBP) from the grains of buckwheat". "The main reason for immunological disorders is low molecular weight proteins, particularly those with digestible starch (SDS), and molecular weights of 15, 22, or 26 kDa" [20]. "From the nutritional point of view, there exist three fractions of starch: rapidly digestible starch (RDS), and slowly resistant starch (RS). It could show a similarity to dietary fiber. In uncooked buckwheat grains, RS continents of dietary fiber are found. Total dietary fiber (TDF) is classified into 2 types insoluble dietary fiber (IDF) and soluble dietary fiber (SDF). In general, IDF includes cellulose, lignins, and certain non-cellulosic polysaccharides, while SDF includes pectin's and some associated non-cellulosic polysaccharides" [21]. "The whole grains contain 7% TDF, while the bran with hull fragments has 40% TDF" [22]. "Dietary fiber consists also of oligosaccharides, polysaccharides, and other hydrophilic derivatives" [23]. "Polyunsaturated fatty acids (PUFA), such as n-3 and n-6, are often referred to as factors provoking the modulation of the immunological system in humans" [24]. "Buckwheat grains were also demonstrated to contain vitamins: B1, B2, and B6" [25]. "Antioxidant activity is the fundamental prophylactic property important for the human organism. A variety of biological functions, e.g. antimutagenic, anticarcinogenic, and antiaging, originate from that property" [26]. "Rutin, quercetin, orientin, vitexin, isovitexin, and isoorientin were identified in buckwheat hulls" [27,28]. "Catechins and phenolic acids are also present in buckwheat grains" [29]. The unique amino acid profile gives buckwheat the power to boost the protein value of beans and cereal grains eaten the same day.

Table 2. The nutritional content of buckwheat in 100g [30]

Name	Amount
Water	9.75 g
Energy	343 kcal
Energy	1435 kj
Protein	13.25 g
Total lipid[fat]	3.4 g
Ash	2.1 g
Carbohydrate, by difference	
Total dietary fibers,	10 g
Calcium	18 mg
Iron	2.2 mg
Magnesium	231 mg
Phosphorous	347 mg
Potassium	460 mg
Sodium	1 mg
Zinc	2.4 mg
Fatty acids, total monosarturated	1.04 g
Fatty acids, total polysaturated	1.039 g
18:2	0.961 g
18:3	0.078 g
aspartic acid	1.133 g
Glutamic acid	2.046 g
Glycine	1.031 g

Acceptable for consumption in Hindu fast especially during Navratri. Buckwheat pancakes, with yeast, are tasty. They are light and foamy... Buckwheat noodles play a major role in the cuisines of Japan (soba) [31]. Buckwheat flour is also used to make Nepali dishes such as dhedo and kachhyamba. Buckwheat starch a jelly called memil muk is made in Korea. Buckwheat is a good honey plant, producing dark, strong mono floral honey.

Note: Eriogonum, a genus of wild North American plants also known as buckwheat [32].

"The anti-oxidative potential is high, mainly in buckwheat leaves, because of the presence of tocopherols and phenolic substances, such as 3-flavonols, flavonol, rutin, phenolic acids, and flavonoids" [33,26,34,35,36]. Only crops containing rutin i.e. in high quantities [25,37]. "This compound has anti-oxidative and anti-inflammatory actions and reduces blood vessel weakness" [38,39]. "Rutin content represents 2-10% of the dry weight of the plant in buckwheat and is essential. Seeds of buckwheat are richer in rutin than albumen" [39,41,42,43,44]. Rutin helps to limit blood platelet coagulation [45]. Pollinated flowers with a normal-sized gynoecium that do not set seeds after pollination are the main contributors to the low seed set in buckwheat that do not set seeds after pollination are the main contribution to the low seed set in buckwheat.

5. EFFECT OF CLIMATE ON BUCKWHEAT

Based on the variation in altitude Tartary buckwheat has frost tolerance capacity since it is grown at higher altitudes and common buckwheat is grown in lower altitude conditions. Gaberscik et al. (1986) found "little frost resistance when they tested buckwheat in a climatic chamber at optimal humidity of 60-80%" [46]. Buckwheat thrives well on sandy, well-drained soils. In limiting moisture it is sensitive to high wind conditions. A condition called 'blasting results in the loss of flowers.

1. **Temperature: "**Seed maturity is reached after an average of 3 months of cultivation in temperate regions.it is frost sensitive so there are very less crops at low altitudes.10°C is the optimal temperature for germination" [47]. "The developmental stage most sensitive to frost is one to two expanded leaves. At this stage, exposure for 4 to 6 h to temperatures between –1 to –3°C is lethal" [47]. "Pollen viability is similarly dependent on temperature and on relative humidity. At 23^{o}c in dry air, pollen loses its viability in one hour" [48].

2. **Water:** "A quantity of 225-315 kg of water is needed to produce 1 kg of seeds" [49]. "Plants quickly wither under drought conditions because of their shallow root system" [50,51]. "water supplied at the reproductive phase is more beneficial than at the reproductive phase. Flooding for more than 10 days at the flowering stage or more than 3 days during the maturation stage affects seed weight" [52].
3. **Photoperiod:** photosensitive varieties should preferentially be cultivated under short photoperiods in order to gain larger yields.

"Buckwheat generally is not attacked by a disease or pest but some of the diseases were recorded. Bugg and Ellis (1990) noted that insect visitation to buckwheat was low during afternoons, whereas insects continued to visit white-sweet clover".[53] Pellett (1976) states that "nectar production is stopped by buckwheat in the afternoon" [54].

6. BIOTECHNOLOGY

According to the researchers reports there is an increase in the numbers of aerobic, mesophilic, and lactic acid bacteria with the buckwheat products. They observed a slight decrease of Enterobacteria and fewer pathogenic bacteria confirming potential prebiotic components in the human gastrointestinal tract. During the extrusion process, biopolymers like proteins and starch coming from several sources underwent physicochemical and structural transformations. The possibility of small and weak crystallite formation at various levels of aggregation can be understood by a change in structure.

Table 3. List of disease in Buckwheat [55]

Name of Disease	Causal Organism
Brown leaf spot disease	*Ascochyta italica*
Chlorotic leaf spot disease	*Alternaria alternate*
Downy mildew disease	*Peronospora ducumet*
iLeaf spot disease	*Septoria polygonicola*
Powdery mildew disease	*Erysiphe polygoni*
Root and collar rot disease	*Sclerotinia libertiana*
Root and stem rot disease	*Phytophthora fagopyri*
Root rot disease	*Fusarium spp.*
Rust disease	*Puccinia fagopyri*
Smut disease	*Sphacelotheca fagopyri*
Stem rot disease	*Botrytis cinerea*
Stipple spot disease	*Bipolaris sorokiniana*

Table 4. List of pests in Buckwheat [55]

Name of pests	Causal Organism
Bruchids	*Acanthecelidsobtectus*
Cutworms	*Cirphis spp.*
Grain moth	*Cephitinea*
Storage beetles	*Sp Mycetophagus sp.*

Table 5. Country holding germplasm collections (> 5 accessions), storage conditions, evaluation of germplasm and details of the collections being store

Country	Storage Conditions	Evaluation Collection	Details of collection
India	medium term	402 acc. were evaluated for 31 trait	60 of F. esculentum var. emarginatum, 316 assesions of F. esculentum 197 of F.tataricum, 25 F. tataricum var. himalianum; 3F.giganteum; 5 F. cymosum

[51]

"The self-incompatibility of buckwheat is of the sporophytic and dimorphic type. The discovery of flower forms with reduced styles was done" [50]. Some special lines adapted to self-pollination were developed. Self-incompatibility was thought to be restored by single dominant genes [56] or possibly by both single and double restorer genes (multiple genes or complex genes) [57]. "Hairy root cultures have been used as a useful model system to study the production of flavonoid and a variety of other secondary metabolites. For example, Pueraria candollei hairy root cultures were established for the production of isoflavonoid" [58]. "In another study, peanut hairy root cultures were developed for testing the bioproduction system for resveratrol" [59]. "Another example involves the pyrrolizidine alkaloids production in hairy root cultures of Echiumrauwolfii" [60]. "Finally, the Taxus media hairy roots that are transformed accumulate the taxane compound. Producing phenolic compounds in vitro in hairy root cultures of common buckwheat and tartary buckwheat has been reported" [61].

It is a short-duration crop requiring a moist and cool temperate climate to grow . Krotov (1963) reports say that flowering temperatures above 30°C is resulting in fruit desiccation and lowering yield [62]. He also found common buckwheat yield increase with high soil moisture. This shows the increase in seed size with an increase in soil moisture content. Adequate soil moisture appears to be essential for good yields .wilting occurs in common buckwheat very badly and grows very slowly when it is affected by low soil moisture. If buckwheat is subjected to high winds and heavy rains it can lodge badly. Buckwheat does not have a good ability to recover from lodging. The tips of the plants grow upward but the stem often remains in contact with the soil and often can be subject to disease and rot [51].

7. ACHIEVEMENTS

Fagopyrins level in buckwheat grains is very low and their isolation process is very difficult. It was reported that fagopyrins found in buckwheat can be utilized in the treatment of type II diabetes [63,64,65]. In New Zealand, biological control Buckwheat is currently being studied and used as a pollen and nectar source [66]. According to Huff and Carroll [67] and Sugiyama et al. [69], cholesterol-lowering effects and a high biological value (BV) are found in buckwheat proteins. protein products addition to diets significantly lowers cholesterol levels in the liver, and gallbladder and suppresses gallstones formation by altering cholesterol metabolism whereas protein extracts are more efficient in lowering the blood cholesterol level, particularly that of LDL and VLDL [69,70,71]. Honey obtained from buckwheat flowers increases the antioxidative potential of human blood serum and in vitro studies indicated that it protects lipoproteins of blood serum against oxidative processes more effectively than saccharic analogs [72]. Buckwheat flour can be also characterized by decreased activities of proteases and α-amylase.

8. CONCLUSION AND FUTURE ASPECTS

Studies on genetic polymorphism of buckwheat have a major scope on the molecular basis of buckwheat allergy [73], and on problems that are commonly important in the breeding of buckwheat [74,75], on the productivity of nectar on quality of buckwheat products [41,77]. The molecular basis for the technological and textural characteristics of buckwheat products is recently studied and has wider applications in future generations [76]. In future research at Morden, Canada, for example, investigations will be conducted along four directors; Breeding of reduced allergic protein lines with good agronomic characteristics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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