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Silver Hull Buckwheat (*Fagopyrum esculentum* Moench) is a Part of Nature that Offers Best Health and Honour

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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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ABSTRACT

The gluten-free pseudocereal *Fagopyrum esculentum* Moench (Silver hull buckwheat) belongs to the Polygonaceae family, which has a long history of both edible and medicinal use. It's a highly nutritious food ingredient that's been shown to have a variety of health benefits. Plasma cholesterol levels are lowered, neuroprotection is given, anticancer, anti-inflammatory, antidiabetic effects are provided, and hypertension conditions are improved thanks to Silver hull buckwheat. It has also been stated to have prebiotic and antioxidant properties. The aim of this review was to include an up-to-date and detailed study of *F. esculentum*. Furthermore, the potential for future research was addressed. Flavonoids, phenolics, fagopyritols, triterpenoids, hormones, and fatty acids are among the various compounds derived from *F. esculentum*. The main active ingredients were believed to be flavonoids and phenolic compounds. All of the information presented leads us to believe that Silver hull buckwheat has a strong medicinal potential. However, further research is needed to better understand its bioactive constituents, their structural functions, and molecular mechanisms underlying.

Keywords: Fagopyrum esculentum; buckwheat; polygonaceae; flavonoids; fagopyrins.

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1. INTRODUCTION

The majority of the people in the modern era are striving to improve living conditions and health care delivery due to growing poverty and demographics. Due to the exorbitant expense of treatments, 70-80 percent of the poor globe relies on traditional plant-based treatments, according to estimates. This reality suggests that by integrating data and testing, valuable and cost-effective diagnostic methods may be derived from diverse flora to satisfy the demands of a constantly evolving planet [1, 2]. As a result, medicinal plants' requirements must not be ignored. The Polygonaceae family of plants holds about 1200 species. Fagopyrum is a Polygonaceae genus with 15 species that are mostly found in the North Temperate Zone [3]. buckwheat, a member of this family, can be found almost anywhere but is primarily grown in the northern hemisphere. buckwheat is a grain grown primarily in Russia and China. Furthermore, in the United States, Canada, and Europe, this product is becoming increasingly popular [4, 5]. The most commonly cultivated species are common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tataricum* Gaertn.) among the major nine agricultural species [6].

Despite the fact that *Fagopyrum esculentum* Moench (common buckwheat) has been a minor crop in many countries, it has survived through centuries of civilization and is now grown in nearly every country where cereals are grown. Although the crop is not a cereal, the seeds are often grouped with cereal grains due to their similar uses [7]. The dehulled groats are boiled as porridge, and the flour is used in the preparation of pancakes, biscuits, noodles, and cereals, among other things. Unlike other cereals, buckwheat protein is of high quality and contains a high amount of the essential amino acid lysine [8]. The flowers and green leaves are used to extract rutin for use in medicine, while the small leaves and shoots are used as leafy vegetables. Honey of exceptional quality is produced by this crop [9, 10]. Consumption of common buckwheat and its enriched products has been linked to a variety of biological and health benefits, including hypocholesterolemia, hypoglycemia, anticancer, antimicrobial, and anti-inflammatory properties. Buckwheat proteins and phenolic compounds are thought to play a role in these advantages, at least in part [11]. Some of these effects have been linked to these compounds' antioxidant potential, but recently found mechanisms of action may also be responsible for the observed health benefits [12, 13]. The goal of this chapter is to go over the most recent research on the health benefits of *F. esculentum*, its proteins, and phytochemicals, as well as the mechanisms that underpin the positive effects ascribed to these compounds.

2. TAXONOMIC POSITION, SYNONYMS AND VERNACULAR NAMES

In 1754, Philip Miller was the first to describe the genus Fagopyrum. It is placed in the Fagopyreae tribe (as the only genus) of the Polygonoideae subfamily. Fagopyrum is a genus of flowering plants of the Polygonaceae family of 15 species primarily found in the North Temperate Zone. Some essential food plants are included, such as *Fagopyrum esculentum* (buckwheat) and *Fagopyrum tataricum* (buckwheat), both of which have similar uses and are classified as pseudo-cereals because they are used in the same way as cereals but do not belong to the Poaceae grass family [14]. The Indian subcontinent, most of Indochina, and central and south-eastern China are all home to this genus. Species have been widely introduced in other regions of the world, including the Glacier, Africa, and South America. *Fagopyrum esculentum* is an annual Asian herb with clusters of small pinkish or white flowers and edible triangular seeds, which are consumed as the main buckwheats worldwide, especially due to their high-quality protein, abundant phenolic compounds, and well-balanced essential amino acids and minerals [15,16]. Many people have named *F. esculentum* over the course of its evolution. *Buckwheat er*, common buckwheat *er chi*, and *er ka* were all names used by the ancient Yi people of Yunnan province. *Qi chi er luo* was the name given to common wild buckwheat, while *chi ruo er luo* was given to wild Tartary buckwheat. Buckwheat's various names have been used to trace its migration through Europe and Asia, and they are still used to confirm its origin. In India, common buckwheat is now known as Ogal. Table 1 shows the taxonomic status of *Fagopyrum esculentum* along with synonyms, while Table 2 communicate the vernacular names [17, 18].

Table 1. Taxonomical classification and synonyms of *F. esculentum*

Domain	**Eukaryote**
Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Division	Tracheobionta
Superdivision	Embryophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Subclass	Caryophyllidae
Order	Caryophyllales
Superorder	Caryophyllanae
Family	Polygonaceae
Subfamily	Polygonoideae
Genus	*Fagopyrum*
Species	*Esculentum*
Preferred Common Name	Buckwheat
Synonyms	*Fagopyrum cereale* (Salisb.) Raf.
	Fagopyrum dryandri Hort. ex Fenzl
	Fagopyrum emarginatum var. kunawarense Meisn.
	Fagopyrum esculentum subsp. ancestralis Ohnishi
	Fagopyrum fagopyrum (L.) H.Karst.
	Fagopyrum sagittatum Gilib.
	Fagopyrum sarracenicum Dumort.
	Fagopyrum subdentatum Gilib.
	Fagopyrum vulgare Hill
	Fagopyrum zuogongense Q.F. Chen
	Helxine fagopyrum Kuntze
	Kunokale carneum Raf.
	Phegopyrum emarginatum (Roth) Peterm.
	Phegopyrum esculentum (Moench) Peterm.
	Polygonum cereale Salisb.
	Polygonum dioicum Buch. Ham. ex Meisn.
	Polygonum elegans Hort. ex Meisn.
	Polygonum emarginatum Roth
	Polygonum fagopyrum L.
	Polygonum gracile Hort. ex Meisn.
	Polygonum macropterum Hort. ex Meisn.
	Polygonum nepalense Hort. Elden. ex Fenzl
	Polygonum pyramidatum Loisel.

Table 2. Vernacular names of *F. esculentum*

Hindi	Kotu or Koti or Kuttu
English	Silver hull buckwheat, Common buckwheat
Assamese	Chutia Lofa, Dhemsi Sak, Dhemsi-sak, Doron, Phapar
Manipuri	Wakha
Malayalam	Kaadu godhi
Angami	Garei (Angami: Naga ethnic group native to the state of Nagaland in North-East India)
Tangkhuls	Harenhan (Tangkhuls: Ethnic group living in the Indo-Burma border)
Garo	Phapar (Garos: Tibeto-Burman ethnic group from the Indian subcontinent)
Dutch	Boekweit
Finland	Tattari
Turkish	Karabuğday
Korean	Memil
Poland	Tatarka gryka or poganka
Russia	Grecicha kul'furnaja
French	ble noir; bouquette; sarrasin; sarrazin
Spanish	Grano sarraceno, Grano turco, alforfón
Portuguese	Trigo sarraceno
Chinese	Qiao mai
Japanese	Soba
Italy	Fagopiro, grano saraceno, sarasin, faggina
Germany	Buchweizen or Heidekorn
Arabic	Al-Hintta Al-Swdaa
Bhutan	Jare
Nepal	Mite phapar
Swedish	Bovete

3. CULTIVATION AND REGIONAL SPREAD

Buckwheat is a grain that is just a few years old. It was mentioned for the first time in China in the 5^{th} century. The shattering perennial buckwheat was most likely domesticated in China. Buckwheat has been a valuable subsistence and cash crop in the Himalayan region for over a thousand years, ranging from northern India to Nepal, Myanmar, Mongolia, China, and Korea. Buckwheat is still very important in these regions, despite the fact that the total area has decreased. In some former Soviet Union republics, it is a common food crop. It is grown in the northernmost parts of Southeast Asia, such as northern Vietnam and northern Thailand, on a sporadic basis. It was introduced into Europe in the early Middle Ages, most likely from Siberia with the Mongols, and quickly became a leading grain crop on poor soils and an important staple food. It became a major food crop in the United States and Canada after being introduced by European emigrants. It is often grown in other parts of the world. However, as chemical fertilizers became more widely used in the early twentieth century, the buckwheat region in Europe and North America shrank dramatically, being replaced by higher-yielding crops such as rye, oats, corn, wheat, and Irish potato. Because of its excellent nutritional qualities, it is currently regaining some popularity in Western countries [17, 19]. The development of varieties with physiological growth determination is one of Russia's most popular buckwheat breeding directions. These varieties have a number of desirable characteristics and properties, including early ripening, simultaneous flowering and ripening, macrocarpousness, lodging resistance, and shedding. Buckwheat varieties with high net photosynthesis productivity in the second half of the generative period, as well as varieties with more simultaneous flowering, were identified [20]. Buckwheat is a real green manure crop for restoring low-productivity land because it grows well on it and produces a green manure crop quickly. A second crop of buckwheat can also be grown and ploughed down as green manure when a crop is harvested early in the year [21]. Buckwheat is a short-season crop (3-4 months) that grows best in a damp, cool temperate climate. Common buckwheat has little frost tolerance and is therefore usually grown at lower altitudes [22]. Sandy, well-drained soils are suitable for buckwheat. Buckwheat is extremely vulnerable to high temperatures and strong, dry winds when moisture is scarce. This typically results in flower failure, a disorder known as 'blasting.' However, it has been recorded that flowering at temperatures above 30°C causes desiccation of the fruit and a reduction in yield. High soil moisture increased yield of common buckwheat, but seed set remained essentially the same. This meant that as the moisture content of the soil increased, so did the seed size. For good yields, it appears that adequate soil moisture is needed [23]. When the soil moisture is too poor, common buckwheat wilts and grows slowly. The plants will sometimes begin to develop again if moisture is given, but maturity will be delayed. Low soil moisture allows cereal crops to mature faster, which is typically the opposite of what occurs. Buckwheat can lodge badly if grown in fertile soil, particularly if subjected to strong winds and heavy rains. Buckwheat plants do not have the same capacity to rebound from lodging as cereal plants. While the plant's tips grow upward, the stem always remains in contact with the soil, making it susceptible to disease and decay [24]. Although there aren't many diseases or pests that affect buckwheat, a few have been recorded like *Sphacelotheca fagopyri* (smut), *Septoria polygonicola* (leaf spot), *Phytophthora fagopyri* (root and stem rot), *Erysiphe polygoni* (powdery mildew), *Ascochyta italica* (brown leaf spot), *Puccinia fagopyri* (rust), *Sclerotinia libertiana* (root and collar rot), *Botrytis cinereu* (stem rot), *Fusarium* spp. (root rot), *Alfernaria alternata* (chlorotic leaf spot), *Bipolaris sorokiniana* (stipple spot disease), *Peronospora ducumeti* (downy mildew). Furthermore, they state that many viruses have been linked to plant height reduction and grain yield losses. However, bruchids, cutworms, grain moths, and storage beetles are major pests [22].

4. PHARMACOBOTANICAL AND PHARMACOGNOSTICAL OVERVIEW

The plant is a towering, slender annual with small leaves and an inflorescence (Fig. 1 and 2). This is an annual herb that grows up to one meter long, is branched, and glabrous. Petiolate leaves with ovate-triangular to triangular blades, 2-8 cm long, acuminate tips, and cordate or nearly hastate bases; upper leaves are smaller and sessile (Fig. 3). Terminal and auxiliary inflorescences branch in thick corymbose or paniculate cymes. A green to reddish membranous sheath (ocrea) with pale ribbing resides at the base of the leaf stem, its upper edge smooth to jagged and the base finely short-hairy (Fig. 4). Stems are erect, green or red, smooth to ridged, unbranched or branching in the upper plant, mostly hairless except for fine lines of hairs on the upper stem and at the leaf nodes, and mostly hairless except for fine lines of hairs on the upper stem and at the leaf nodes [25, 26]. Flowers are 6 mm in diameter and white or pink; the pedicel is 2-3 mm long and articulate; the perianths are 3 mm long; the 8 yellow nectaries alternate with the stamens; heterostyly, the stigma is capitate (Fig. 5). Triquetrous, with an acute angle and a length of more than 5 mm,

Fig. 1. Plate photograph of *Fagopyrum esculentum* plant

Fig. 2. *Fagopyrum esculentum* plant

Fig. 3. Leaf of *Fagopyrum esculentum*

Fig. 4. Leaf stalk of *F. esculentum*

Fig. 5. Flowers of *Fagopyrum esculentum*

more than twice the length of the recurring perianths, the achene is triquetrous (Fig. 6). The plant blooms and bears fruit from June to September and is brown or black-brown in colour (Fig. 7). The nectar secreted by glands at the base of the ovary draws insects to the flowers of cross-pollinating buckwheat plants. Bees and other insects facilitate pollen distribution because buckwheat attracts a variety of insects, including pest predators like syrphids, due to its continuous blooming. It's a good foraging plant for bees, for using its nectar to make delicious honey [27, 28]. Buckwheat (*F. esculentum*), an important crop plant native to Central Asia, has one-seeded achenes. The three-sided achenes look like miniature beech tree nuts (Fagus). Because of the similarity, the German word "buchweizen" (beech-wheat) was coined, which was later transformed to the current name of buckwheat. Several brands of hot and cold breakfast cereals use hulled achenes or groats. Buckwheat flour is used to make "kasha," a nutritious porridge popular in Russia. Fruit is a dry seed (achene) up to 14 inches long, much longer than the tepals, firmly 3-sided, minutely winged along the angles, smooth across the top, light brown with darker streaks at maturity. The seed's triangular shape, dark brown colour, 8 mm length, and 6 mm width were determined by morphological studies. The Testa or pericarp (seed coat), endosperm, embryo, and sclerenchyma cells were all visible under the microscope in the transverse portion of the seed. Physiochemical parameters showed a foreign matter content of 0.30% and a crude fibre content of 1.44%. The values for total ash, acid insoluble ash, and water-soluble ash were 6.71%, 1.90%, and 3.90%, respectively. The extractive values for alcohol soluble and water-soluble extracts were 65.02mg/g and 12.71mg/g, respectively. The swelling index was 0.50ml/g, and the foaming index was less than 100. The loss due to drying was 4.02% [29]. The plants have a short taproot and fine lateral roots, resulting in a root system that accounts for 3-4 percent of the total plant's weight [30].

Fig. 6. Achene and seed of *F. esculentum*

Fig. 7. Fruits with flowers of *F. esculentum*

5. IDEOLOGICAL AND ECONOMIC REPERCUSSIONS OF BUCKWHEAT AS A FOOD SUPPLY

Buckwheat grain is primarily grown for human consumption and animal feed, but it can also be used as a vegetable, a manure crop, a weed-controlling smother crop, and a source of buckwheat honey. Buckwheat production has the potential to be a reasonably profitable business, though productivity is still poor. Possible reasons for the low profit include the farmer's low priority for the current crop in relation to other competing crops, the allocation of marginal and unirrigated land for buckwheat output, limited production technologies, and under and over utilization of production inputs. Besides that, increasing the number of resources used in buckwheat production, such as tractor resources, manures, and fertilizers, will result in a higher gross return per area unit of land. Buckwheat is a popular grain that is eaten in a variety of ways in various countries. Fortunately, buckwheat is currently underappreciated and underutilized as a nutritious food and a viable alternative crop plant, especially in developed countries. In comparison to other significant cereal crop species, buckwheat has received little crop improvement attention in recent decades. Buckwheat is still predominantly grown as a primitive crop today, in much the same way it was hundreds of years ago, with yields virtually unchanged. Buckwheat is a versatile crop, with nearly any part of the plant being used in a number of ways. Rutin, a medicinal product, is found in the herb. Buck wheat, also known as *Fagopyri herba*, is a rutin-rich plant that has historically been used to make tea to treat hypertonia. Honeybees feed on the nectar produced by the flower. Buckwheat can be used in a variety of ways in the kitchen. The dehulled grains are boiled and eaten. Flour may be made from whole grains or dehulled grains. The hulls of buckwheat are used to fill a number of upholstered items, including pillows. Straw is an excellent livestock feed. It's always eaten as a noodle soba in Japan. Buckwheat flour is commonly mixed with wheat flour in Europe and North America to make pancakes, biscuits, noodles, cereals, and as a meat extender. Porridge and soup are made with groats (Fig. 8) and flour in Russia and Poland. It's used to stuff fish in Sweden. Buckwheat is a staple food in many hilly areas of Southeast Asia. Unleavened bread chapattis are made with this flour. It's also fried after being combined with water to make a crispy pakora. Parathas can also be made with the flour and potatoes. It's also used during fasts and spiritual celebrations. Buckwheat is used to make alcoholic beverages, with buckwheat liquor being said to have medicinal properties. Buckwheat is rumoured to be used in the manufacture of vinegar in China. In many parts of the Indian subcontinent, buckwheat is grown as a leafy vegetable crop. The plants' tender leafy shoots are harvested and used to make

Fig. 8. Buckwheat groats (untoasted and toasted) obtained from *F. esculentum*

dishes. Buckwheat has long been used by hunters as a food and cover crop for wildlife. Buckwheat is eaten by deer, and they will start foraging as soon as a few seeds have grown. Wild turkeys, pheasants, grouse, waterfowl, and other birds consume the grain. The crop is usually planted but not harvested, so the remaining plants provide food and shelter for wildlife [17, 19, 31, 32].

6. DIETARY AND BIOCHEMICAL RELEVANT

Buckwheat is a pseudocereal with high nutritional and nutraceutical properties. Buckwheat is known to be rich in high quality carbohydrates, protein and amino acid, fatty acid, vitamins, minerals, and bioactive compounds such as polyphenols. However, the total content of components depends on variety or environmental factors. Buckwheat contains abundant in mineral elements such as K, P, Cu, Ca, Se, Mg, Ba, B, I, Fe, Pt, Zn, Co as well as cyanide, phytin and riboflavin [33]. Buckwheat has a higher concentration of K, Mg, P, Ca, Fe, Zn, Cr, Cu, and Mn than other cereals [34]. As a result, buckwheat may be a valuable source of microelements like Fe, Mn, and Zn. Furthermore, as compared to other crops, buckwheat has a high bioavailability of Zn, Cu, and K. Mineral distribution in the seed varies depending on the tissues, with mineral concentrations varying from 2.0 to 2.5 percent in whole grains, 1.8 to 2.0 percent in kernels, 2.2 to 3.5 percent in dehulled grains, 0.8 to 9% in flour, and 3.4 to 4.2 percent in hulls. It was also asserted that P, K, and Mg are most abundant in bran, and trace elements are abundant in the outer membrane of seeds and seed coat. The embryo, on the other hand, contains valuable essential elements such as Mg, P, S, K, Mn, Fe, and Zn. Buckwheat is the only grain crop known to have antioxidant, anti-inflammatory, and anti-carcinogenic properties due to its high rutin content. Buckwheat has been found to contain more than 130 major polyphenols, in addition to rutin [35]. Buckwheat is rich in manganese, phosphorous, and copper. Copper is required for the production of red blood cells. Magnesium relaxes blood vessels leading to the brain and has been shown to help with depression and headaches. Buckwheat is high in Folate, which aids in the production and maintenance of new cells, especially red blood cells. It's especially critical for pregnant women to get enough folate. Even if they aren't planning to have children, they should start eating folate-rich foods like buckwheat. Because buckwheat grains contain more B-complex vitamins, consuming enough folate before and during pregnancy helps to prevent major birth defects affecting the baby's brain [36]. Its protein content is high. The total amino acid concentration was 31%. The main amino acids were glutamine, glutamic acid and arginine, apart from that it also contains lysine, histidine, aspartic acid, threonine, serine, proline, half cystine, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine and tryptophan. It also contains 18% albumin, 43% globulin, 1% prolamine, and 38% gluetin. *Fagopyrum esculentum* protein concentrates and hydrolysate have the ability to be useful as food ingredients.

It's also high in dietary fibres, which has a beneficial physiological impact in the gastrointestinal tract and affects the metabolism of other nutrients significantly. Since buckwheat seeds are gluten-free, they are ideal for celiac disease sufferers and buckwheat intake decreases the risk of diabetes due to its high magnesium content [37-39]. The moisture content of the buckwheat plant (*Fagopyrum esculentum*) and products made from its seeds was 6 to 8%. The lowest moisture content was found in roots (4.3%), while the highest was found in both flours (around 12%). Peels had the lowest amount of crude protein among buckwheat products, at 3.5%. On the other hand, the highest crude protein content of the buckwheat plant was found in the leaves (22.7%) and blossoms (19.1%). Buckwheat seed is packed full of starch, but the amount varies. The starch content of whole grain common buckwheat ranges from 59 to 70% dry matter, but the concentration varies depending on the method of extraction and cultivar. Amylose content in buckwheat granules ranges from 15 to 52 percent, with polymerization degrees ranging from 12 to 45 glucose units. 0.65-0.76 percent reducing sugars, 0.79-1.16 percent oligosaccharides, and 0.1-0.2 percent non-starchy polysaccharides are also found in buckwheat grains. Sucrose is the most common sugar with a low molecular weight. A small amount of arabinose, xylose, glucose, and the disaccharide melibiose are present. Likewise, the total lipid content of common buckwheat seeds ranges from 1.5 to 3.7 percent. The embryo has the highest concentration (7-14%), while the hull has the lowest concentration (0.4-0.9%). Total lipids in groats or dehulled buckwheat seeds range from 2.1 to 2.6 percent, with 81-85 percent neutral lipids, 8-11 percent phospholipids, and 3-55% glycolipids. Palmitic, oleic, linoleic, stearic, linolenic, arachide, behenic, and lignoceric are the major fatty acids found in common buckwheat. The 16 and 18-carbon acids are the most common in all cereals. Long-chain acids such as arachidic, behenic, and lignoceric, which account for about 8% of total acids in buckwheat, are minor components or absent from cereals. Buckwheat had a dry matter content of 60 to 70% in buckwheat products. Whereas peels had the lowest fat content 0.6 %. Rutin concentrations were found to be highest in blossoms and leaves, at 83.6 and 69.9 mg per gram, respectively. Buckwheat goods, on the other hand, had the lowest concentration of rutin, with less than 1 mg per gram of dry matter. Best-known buckwheat has a phenolic content of 0.735% to 0.79%. Table 3 reflects the average rutin concentration, moisture, starch content, crude protein, and fat content of the buckwheat plant [40]. Buckwheat includes flavonols, anthocyanins, and C-glucosyl-flavones, three of the several forms of flavonoids [41]. Buckwheat's leaves, roots, flowers, and fruit contain rutin (quercetin-3-rutinoside), a well-known flavonol diglucoside used to treat vascular disorders. Quercetin (quercetin 3-rhamnoside) and hyperin are two other flavonols that have been identified (quercetin 3-galactoside). The hypocotyls of buckwheat seedlings produce at least three red pigments. One of these is cyanidin, and the other two are considered to be cyanidin glycosides. Vitexin, isovitexin, orientin, and isoorientin are C-glycosylflavones found in buckwheat seedling cotyledons. The hydro benzoic acids, synigic, p-hydroxy-benzoic, vanillic, and *p*-coumaric acids are the phenolic acids present in buckwheat seed. Popular buckwheat seeds contain soluble oligomeric condensed tannins, which, together with phenolic acids, provide astrigency and affect the colour and nutritional value of buckwheat products [21]. N-feruloltyramine and 7-hydroxy-N-feruloyltyramine are found in high concentrations in the roots and at very low levels in other parts of the plant. Both sections of the plant contain small amounts of protocatechic acid, gentisic-5-O-glucoside, p-hydroxybenzoic acid, p-cumaric acid, and ferulic acid [31].

Table 3. The average rutin concentration, moisture, starch content, crude protein, and fat content of *F. esculentum* (buckwheat) plants

	Moisture (%)	Crude protein (%)	Starch (%)	Fat (%)	Rutin (mg/g)
Roots	4.3	5.6	0	4.3	3.6
Stalks	7.7	6.5	1.1	2.6	0.5
Leaves	7.5	22.7	6.0	3.1	69.9
Blossoms	6.5	19.1	-	5.7	83.6
Peels	6.1	3.5	57.2	0.6	0.1
Groats	8.3	13.1	69.5	3.4	0.1
Flour	11.5	12.9	67.9	4.1	0.1
Wholemeal flour	11.9	14.4	61.6	4.1	0.6

Dry matter, complete digest, protein, fat, fibres, mineral matter, and rutin, isoorientin, and orientin are antioxidants contained in *Fagopyrum esculentum* feed, straw, and green fodder [32]. Table 4 demonstrates the nutritional potential of buckwheat based on its biochemical profile.

Table 4. Per 100 gm of buckwheat (*F. esculentum*), nutritional potential and biochemical value

Principle	Nutritive value
Energy	323- 343 kcal
Carbohydrates	59-71.5 g
Total Fat	2.4-3.4 g
Saturated fat	741 mg
Monounsaturated fat	0.8-1.04 g
Polyunsaturated fat	1-1.039 g
omega-3	50-78 mg
omega-6	961 mg-1g
Protein	10.3- 13.25 g
Dietary fibres	10 g
Crude Fibre	8.6 g
Vitamins	**Proportions**
Thiamine (B_1)	0.101 mg
Riboflavin (B_2)	0.425 mg
Niacin (B_3)	7.02 mg
Pantothenic acid (B_5)	1.233 mg
Vitamin ($B_{6)}$	0.21 mg
Folate (B_9)	30 µg
Tocopherols	4.1 mg
Minerals/trace elements	**Extents**
Calcium	18-64 mg
Iron	2.2-15.5 mg
Sodium	1-16.2 mg
Potassium	460-720 mg
Magnesium	227-231 mg
Manganese	1.3-2.8 mg
Copper	0.17-1.8 mg
Zinc	2-2.4 mg
Selenium	8.3 µg
Phosphorus	347-355 mg

7. REFLECTION OF BIOACTIVE COMPOUNDS AND PHYTOMOLECULES

Polyphenols, alkaloids, terpenoids, steroids, proteins, minerals, condensed tannins, vitamins (B_1, B_2, B_3, B_5, B_6, C and E), squalene, iminosugars and phenylpropanoid glycosides are among the constituents of *Fagopyrum esculentum* that have been isolated [42]. Flavonoids in Fagopyrum buckwheat demonstrated remarkable antioxidant and cardio-cerebral vascular protective effects, making these buckwheat's valuable dietary supplements [43, 44]. Polyphenols, which are biologically active and have a wide range of pharmacological properties such as antibacterial, antivirus, anti-inflammation, and anti-oxidation properties, are one of the most important constituents found in Chinese herbal medicines. The main phenolics compounds present in buckwheat are rutin, quercetin, kaempferol-3-rutinoside, aromadendrin-3-*O*-D-galactoside, taxifolin-3-*O*-D-xyloside and a trace quantity of a flavonol triglycoside, which means it has a ton of antioxidant activity. Rutin was not present in cereals or pseudo-cereals, with the exception of buckwheat, which produces the majority of rutin in the inflorescence, stalks, and upper leaves and can be used as a good source of dietary rutin [45-47]. These buckwheat's also contained catechins (flavanols) and condensed tannins (proanthocyanidins). (-)-Epicatechin, (-)-epicatechin-3-*O*-p-hydroxybenzoate, (-)-epicatechin-3-*O*-(3,4-di-O-methyl)-gallate and (+)-catechin-7-*O*-glucoside were isolated from buckwheat groats [43] and (−)-epicatechin-3-*O*-gallate, procyanidin B-2, and procyanidin B2-3'-*O*-gallate were found in buckwheat callus and hairy roots [48]. Simultaneously numerous sterols like campesterol, stigmasterol and sitosterol gift in buckwheat seeds, additionally phytosterols conjointly contained in buckwheat pollen like campesterol, stigmasterol, methylenecholesterol, isofucosterol, cholesterol, brassicasterol, 23-dehydrocampestanol, 7-dehydro-24-methyldesmonstanol, 23-dehydrositosterol, 7-dehydro-24-ethyldesmostanol and sitosterol [49]. Buckwheat flowers contain substantial amounts of fluorescent phototoxic compounds such as fagopyrins and protofagopyrins [50]. Allelochemicals in buckwheat include ferulic, caffeic, and chlorogenic acids, as well as fatty acids. Eugenol, coniferyl alcohol, and 3,4,5-trimethoxyphenol were found in buckwheat stems, leaves, and roots [51]. The alkaloids and its derivatives, such as fagomine, 4-piperidone, and 2-piperidinomethanol, were found in above-ground buckwheat sections and had a strong inhibitory effect on lettuce development [52]. Chemical analysis showed that the plant also contained, cyclitol: (fagopyritol A1, fagopyritol A2, fagopyritol A3, fagopyritol B1, fagopyritol B2 and fagopyritol B3); triterpenoids: (olean-12-en-3-ol and urs-12-en-3-ol); fatty Acids like 6, 7-dihydroxy-3,7-dimethyl-octa-2(Z),4(E)-dienoic acid, 6, 7-dihydroxy-3,7-dimethyl-octa-2(E), 4(E)-dienoic acid and 4, 7-dihydroxy-3,7-dimethyl-octa-2(E), 5(E)-dienoic acid; γ-tocopherol and squalene. Consequently, sucrose (42% of total), D-chiro-inositol, myo-inositol, galactinol, raffinose, and stachyose (1% of total) were among the other soluble carbohydrates captured by high-resolution gas chromatography, but no reducing sugars were found [53-56]. Buckwheat has a distinct flavour and aroma. Different methods were used to extract volatiles from freshly ground buckwheat flour. 2,5-dimethyl-4-hydroxy-3(2H)-furanone, (E,E)-2,4-decadienal, phenylacetaldehyde, 2-methoxy-4-vinylphenol, (E)-2-nonenal, decanal, hexanal, and salicylaldehyde (2-hydroxybenzaldehyde) were the compounds that contributed the most to the buckwheat aroma [57]. In addition, when looking for bioactive compounds against human pancreatic cancer cells, Lapathoside A, a phenylpropanoid ester, was isolated and recorded from the roots of buckwheat [58]. In buckwheat flour, reverse phase high performance liquid chromatography combined with electrospray ionization-time of flight-mass spectrometry was used to isolate and classify thirty phenolic compounds, including new compounds such as 2-hydroxy-3-*O*-β-d-glucopyranosil-benzoic acid, 1-O-caffeoyl-6-*O*-alpha-rhamnopyranosyl-β-glycopyranoside and epicatechin-3-(3″-*O*-methyl) gallate in buckwheat flour [59]. Several flavonols were detected in the embryo, endosperm, testa, and hull of buckwheat using high-performance liquid chromatography photodiode array-mass spectroscopy, including the predominant flavonoid rutin and minor flavonoids like quercetin 3-*O*-rutinoside-3'-*O*-β-glucopyranoside, kaempferol 3-*O*-rutinoside, and quercetin [60]. From buckwheat seed ethanol extract, major constituents such as 9-octadecenamide, n-hexadecanoic acid, ethyl linolate, 9-octadecenoic acid (z), 2, 3-dihydroxypropyl ester, ergost-5-en-3-ol (3.beta.24r), gamma-sitosterol, lupeol, and fumaric acid were detected by using gas chromatography-mass spectrometry with electron ionisation. In addition, Digalactosyl myo-inositol [(α-d-galactopyranosyl-(1→6)-α-d-galactopyranosyl-(1→1)-1l-myo-inositol)], trigalactosyl myo-inositol [α-d-galactopyranosyl-(1→6)-α-d-galactopyranosyl-(1→6)-α-d-galactopyranosyl-(1→1)-1l-myo-inositol], and trigalactosyl d-chiro-inositol [α-d-galactopyranosyl-(1→6)-α-d-galactopyranosyl-(1→6)-α-d-galactopyranosyl-(1→2)-1d-chiro-inositol] were also noted in the seeds of common buckwheat [61]. Furthermore, Nonanoic acid, (E)-3-hexen-1-ol, and benzothiazole were the main constituents among the 28 identified components, accounting for 92.89% of the total oil of *F. esculentum* were isolated from fresh buckwheat flowers by hydrodistillation and gas chromatography-mass spectrometry method [62]. One of the most important factors in distinguishing honeys from different botanical/floral origins is the presence of volatile organic compounds. Among the identified volatile organic compounds, 3-methylbutanal, butanoic acid, pentanoic acid, and isovaleric acid were significantly higher in the buckwheat honey samples. Other compounds, such as 3-methyl-2-buten-1-ol, 2-butanone, 2-hydroxy-3-pentanone, 4-methylpentanoic acid, 4-pentanoic acid, butanal, 2-methylbutanal, pentanal, dihydro-2-methyl-3(2H)-furanone, 5-methylfurfural, and cis-linalool oxide, were only found in honeys containing buckwheat pollen grains. Buckwheat honey's aromatic and organoleptic properties are attributed to these compounds, which may be considered interesting as potential "variety markers" for botanical determination [63]. In brief the list of assorted category phytochemicals catalogues in Table 5.

Tables 5. Highlight of bioactive compounds captured in *Fagopyrum esculentum*

Flavonoids	*Flavonols*	Rutin; Kaempferol-3-*O*-sophoroside; Kaempferol-3-*O*-glucoside-7-*O*-glucoside; Myricetin; Isoquercitrin; Isoquercetin; Quercetin; Quercetin-3-*O*-β-D-galactoside; Taxifolin-3-*O*-D-xyloside
	Flavones	Luteolin; Vitexin; Isovitexin; Orientin; Isoorientin; Homoorientin
	Flavanones	Hesperetin-7-rutinoside; Hesperetin 7-O-neohesperidoside; Hesperetin-*O*-hexosyl-*O*-hexoside; Hesperetin 5-*O*-glucoside; Hesperetin-*O*-malonylhexoside; Naringenin; Naringenin chalcone; Naringenin-*O*-malonylhexoside; Naringenin 7-O-glucoside; Phloretin; Homoeriodictyol.
	Flavan-3-ol	Catechin; (+)-catechin-7-*O*-glucoside; Epicatechin; Epicatechin-3-*O*-(3,4-di-*O*-methyl)-gallate; (-)-

		epicatechin-3-*O*-*p*-hydroxybenzoate; Epicatechin gallate; Epiafzelechin-(4–6)-epicatechin; Epiafzelechin-(4-8)-epicatechin-*p*-OH-benzoate; Epiafzelechin-(4-8)-epicatechin-methyl gallate; Epicatechin(4-8)-epicatechin-*O*-(3,4-dimethyl)-gallate; Epiafzelechin-(4-8)-epicatechin(3,4-dimethyl)-gallate; Epiafzelechin-(4-8)-epiafzelechin-(4-8)-epicatechin; Epiafzelechin-(4-8)-epiafzelechin-(4-8)-epicatechin-*O*-(3,4-dimethyl)-gallate.
	Anthocyanins	Cyanidin 3-*O*-glucoside; Cyaniding 3-*O*-rutinoside; Cyanidin 3-*O*-galactoside; Cyanidin 3-*O*-galactopyranosyl-rhamnoside.
	Flavonolignan	Tricin-4′-*O*-(β-guaiacylglyceryl)-ether-*O*-hexoside; Tricin-7-*O*-β-guaiacylglycerol; Tricin-4′-*O*-β-guaiacylglycerol; Tricin-4′-*O*-syringic acid; Tricin 4′-*O*-(syringyl alcohol) ether-5-*O*-hexoside; Tricin-4′-*O*-(syringyl alcohol) ether-7-*O*-hexoside.
Oligomeric flavonoids	*Proanthocyanidins*	Procyanidin A1; Procyanidin A2; Procyanidin A3; Procyanidin B2; Procyanidin B3; Procyanidin B5.
Isoflavones	6-hydroxydaidzein; 2′-hydroxydaidzein; Sissotrin; Sissotrin; Formononetin; Glycitin; Genistein-7-*O*-glucoside; Formononetin-7-*O*-glucoside	
Fagopyrins	Fagopyrin A; Fagopyrin B; Fagopyrin C; Fagopyrin D; Fagopyrin E; Fagopyrin F	
Alkaloids and derivatives	Fagomine; 4-piperidone; 2-piperidinomethanol.	
Steroids	23S-methylcholesterol; Stigmast-5-en-3-ol; Stigmast-5,24-dien-3-ol; *Trans*-stigmast-5,22-dien-3-ol; 6-hydroxystigmasta-4,22-dien-3-one; Campesterol, Stigmasterol; Methylenecholesterol; Isofucosterol; Cholesterol; Brassicasterol; Sitosterol; 23-dehydrocampestanol; 7-dehydro-24-methyldesmonstanol; 23-dehydrositosterol; 7-dehydro-24-ethyldesmostanol.	
Cyclitol	Fagopyritol A1; Fagopyritol A2; Fagopyritol A3; Fagopyritol B1; Fagopyritol B2; Fagopyritol B3.	
Triterpenoids	Olean-12-en-3-ol; Urs-12-en-3-ol; Oleanolic acid.	
Stilbenes	Resveratrol	
Phenolic derivatives	Protocatechuic acid; 3,4-dihydroxybenzaldehyde; Chlorogenic acid; Protocatechuic acid.	
Vitamins	Thiamine (B_1); Riboflavin (B_2); Niacin (B_3); Pantothenic acid (B_5); Pyridoxine (B_6); Ascorbic acid (C); γ-tocopherol (E).	
Fatty Acids	6,7-dihydroxy-3,7-dimethyl-octa-2(Z),4(E)-dienoic acid; 6,7-dihydroxy-3,7-dimethyl-octa-2(E), 4(E)-dienoic acid; 4,7-dihydroxy-3,7-dimethyl-octa-2(E),5(E)-dienoic acid; Pelargonic acid; Caprylic acid; Capric acid; Undecanoic acid; Lauric acid; Palmitic acid.	
Volatile oils/ liquid	3-Penten-2-one; (E)-3-Hexen-1-ol; (E)-2-Octenal; Pentadecane; (-)-α-Terpineol.	
Fatty alcohol	1-Hexanol; 1-Octanol; Behenyl alcohols; Oleyl alcohols.	
Soluble carbohydrates	Sucrose; D-chiro-inositol; myo-inositol; galactinol; raffinose; stachyose.	
Miscellaneous compounds	(E)-3-Hexen-1-yl acetate; Heptadecane; Benzene acetaldehyde; Eicosane; 5-Methyl-2-furancarboxaldehyde; Octadecane; Tetradecanal; Benzothiazole; Hexadecenal; Isopropyl myristate; Heneicosane; 6,10,14-Trimethyl-2-pentadecanone; Betaine; squalene; n-butyl-β-D-fructopyranoside.	

8. ETHNOARCHAEOLOGY AND NATUROPATHIC REMEDIES

Ethnobotanical reports on common buckwheat are scarce. It is considered a healthy food in Japan due to its rutin content. This is said to help increase blood vessel elasticity and thus prevent artery hardening. Traditional folk medicine has used *F. esculentum* for several therapeutic purposes. The leaves of buckwheat are a good source of rutin, which makes it a common medicinal herb. Rutin dilates blood vessels, decreases capillary permeability, and lowers blood pressure, making it effective in the treatment of a variety of circulatory problems. Internally, the leaves are used to treat high blood pressure, gout, varicose veins, chilblains, radiation exposure, and other ailments. It works best when taken with vitamin C, which helps absorption. It's a specific remedy for haemorrhage into the retina, and it's mostly mixed with lime flowers. A dressing made from the seeds has been used to help nursing mothers get their milk flowing again. The herb has been used to treat erysipelas with an infusion (an acute infectious skin disease). The leaves have been used to produce a homeopathic cure. It is used to treat eczema as well as liver problems. Buckwheat is used in Meghalaya folklore to treat high blood pressure and constipation. It's often used to set bones by adding a ground-leaf paste [64]. Colic, choleric diarrhoea, and intestinal obstructions are common uses for the seed. Rheumatic pains, lung diseases, and typhoid are treated with root decoction, and urinary problems are treated with root juice. It is used in the treatment of pulmonary sepsis in China. A poultice made from the seeds has been used to help nursing mothers restore their lactation. The herb has been used to treat erysipelas with an infusion [65]. Seeds have the ability to invigorate the spleen, avoiding food stagnation and descending qi-flowing, according to Traditional Chinese Medicine theory. The therapeutic function of the leaf and stem, according to the Chinese Materia Medicine Dictionary, includes treating choking, ulcers, haemostasis, and bathing wounds. They also report that the book Classified Materia Medica for Emergency indicates that the leaf can be eaten and can improve vision and hearing, as well as keep negative energy at bay. The plant is often used to treat hypertension, which is thought to be due to the fact that the leaf of buckwheat is eaten in rural areas where the incidence is lower [66]. Buckwheat has been reported to help with stomach problems in Nepal. Because of its medicinal properties, jang, a local buckwheat brew, commands a higher price in some places. Clinical studies on 75 diabetic patients who were given buckwheat biscuits demonstrated a reduction in blood sugar levels. According to other reports from China, buckwheat has a hypoglycaemic impact. Currently, buckwheat noodles can be obtained as a diabetes treatment [67]. It's also mentioned in the British Herbal Pharmacopoeia as an anti-haemorrhagic and hypotensive medication, and it's used in Korean folk medicine for anti-inflammation, detoxification, and fever lowering. Its perisperms can be used as a source of energy in gas-producing plants. Textile Fabrics are coloured with a dye derived from the hulls, while blue dye is made from the stems and brown dye is made from the flowers [68-70]. Periodontitis and gum bleeding have been confirmed to be treated with *F. esculentum*. Patients who brushed their teeth and gargled with buckwheat flour every morning and evening improved by 62 percent. Buckwheat was thought to have this effect because it contains several microelements, vitamins, and is particularly high in quercetin and rutin. They claim that these special formulations help to preserve blood capillary resistance by reducing fragility and permeability, preserving and restoring elasticity, and reducing inflammation [71]. Diarrhea, eczema, multiple eye affections, headache, burning eruptions, pruritus pudenda, sore throat, tonsillitis, uvulitis, nausea, coryza, and leucorrhoea have all been treated with *Fagopyrum esculentum* in homoeopathy. This treatment also helped with styes, conjunctivitis, nasal obstruction, burning in the rectum, joint pain, boils, and a productive cough [72].

9. BUCKWHEAT BASED BEVERAGES AND GREEN TEA

It's important to think about how the processing of buckwheat into tea will affect the bioactive compounds in the grain. Making tea from raw buckwheat seeds entails a number of steps. Before being removed from their hulls, raw whole seeds are soaked in water, steamed, and dried. After that, the dehulled groats are roasted to make the tea. The implications of these thermal processing techniques on buckwheat proteins are found to be influenced by the buckwheat's lipid content. While lipids can help buckwheat, proteins maintain their thermal stability, they can also cause buckwheat globulins to become disrupted. For the preservation of buckwheat globulins during thermal treatment, it is recommended that a suitable amount of lipids, such as 6.5%, be present [73]. Buckwheat tea, also known as Sobacha in Japan, is a beverage made from the roasted grains, leaves, or flowers of the buckwheat plant. Buckwheat has been used to replace other grains in gluten-free beer in recent years. Buckwheat can be used in the same manner as barley to make a malt that can be used to make a mash that will yield a beer free of gliadin and hordein (gluten), making it ideal for coeliacs and those that are allergic to such glycoproteins. Apart from health benefits, tea is enjoyed for fun. In Korea, buckwheat tea is known as memil-cha, and in China, kuqiao-cha. The tea has a light fragrance and a dry, nutty, earthy flavour. Brew the buckwheat tea like you would any other tea and drink it straight up, without any sweetener or milk. Drinking buckwheat tea has many health benefits, including helping in digestion, improving heart health, preventing kidney complications, lowering cancer risk, and encouraging weight loss. When consumed in moderation, buckwheat is not associated with many harmful health effects. Some individuals, however, may be allergic to buckwheat. Treatment with buckwheat herb tea is safe and can have a beneficial effect on patients with chronic venous insufficiency, preventing the formation of oedema [74]. Similarly, Rutin, quercetin, and C-glucoflavones were also present in the buckwheat hull, but the overall phenolic content was slightly lower than that of green tea leaves. The key flavonoids contained in buckwheat hull tea were rutin and vitexin. As compared to green tea, buckwheat hull tea had lower antioxidant potential and inhibitory activity against the development of fluorescent advanced glycation end products [75]. Further study compared the antioxidant properties of buckwheat after thermal processing such as microwave heating, pressured steam heating, and roasting. The most damaging to the antioxidant properties was found to be pressured steam-heating. These findings suggest that processing methods should be optimized in order to produce buckwheat tea with the highest concentration of beneficial active compounds. Buckwheat tea contains less calories and is therefore an excellent substitute for high-calorie beverages. Buckwheat tea will help you lose weight by replacing high-calorie drinks [76].

10. PHARMACOLOGICAL PROFILE

Fagopyrum esculentum has a significant health benefits due to its well-balanced amino acid sequence and high lysine and arginine content. Buckwheat protein has been shown to have a wide range of physiological functions, including curing chronic human diseases, reducing blood cholesterin, inhibiting mammary cancer caused by 7,12-Dimethylbenzanthracene, and preventing gallstones, and so many more. In humans, buckwheat consumption is linked to a lower risk of hyperglycaemia and enhanced glucose tolerance in diabetics. Furthermore, buckwheat, a globally grown crop, is one of our most significant food sources. It also contains high-value proteins, balanced vitamins, and catechins, in addition to numerous polyphenols. Vitamin E supplementation has been linked to a lower risk of cardiovascular disease, a lower risk of Alzheimer's disease and prostate cancer, a stronger immune system, and a delay in age-related cataracts and macular degeneration.

10.1 Antioxidant Excellency

Exogenous and endogenous reactive oxygen species are constantly attacking the human body, causing oxidative damage to the cells. The hydroxyl radical is a reactive oxygen species that is known to cause damage to cellular components, including DNA. It is typically highly reactive and short-lived. *Fagopyrum esculentum*, on the other hand, contains a variety of antioxidants, including rutin, quercitrin, quercetin, tocopherols, and phenolic acids, which may help to mitigate the damage. The protective effects of ethanolic extracts from buckwheat groats on DNA damage caused by hydroxyl radicals were investigated by some researchers. Under *in-vitro* conditions, the results showed that 70% of *F. esculentum* can effectively inhibit non-site-specific hydroxyl radical-mediated DNA damage and site-specific hydroxyl radical-mediated DNA strand breaks, implying that *F. esculentum* can be used not only as a readily available source of natural antioxidants but also as an ingredient in functional foods related to prevention and control diseases associated with carcinogenesis. Phenolics are potent antioxidants that help to prevent disease in a variety of ways. Quercetin, rutin, kaempferol, catechins, and other compounds that are abundant in *Fagopyrum esculentum* are included in this large group. The abundance of phenolic compounds in Fagopyrum buckwheat's leads to their widespread use as a medicinal food [77, 78]. According to this, the antioxidant activity of buckwheat's is influenced by the sum of rutin and total flavonoids present [79]. The yield, total phenolics, and antioxidant activity of buckwheat (*F. esculentum*) extracts were significantly affected by different polarity extracting solvents. According to the β-carotene bleaching process, the methanolic extracts had the highest antioxidant activity coefficient (AAC) of 627±40.0 at 200 mg/L and the longest induction time of 7.0±0.2 h, while the acetone extract had the highest scavenging activity of 78.6±6.2 percent at 0.1 mg/mL according to the DPPH method [80]. Furthermore, the ethanolic extract of *F. esculentum* significantly reduced non-site-specific hydroxyl radical-mediated DNA damage and site-specific hydroxyl radical-mediated DNA strand breaks *in-vitro*, owing to its strong antioxidant activity [81]. In DPPH assay and the reducing power method were used to assess the antioxidant capacity of *F. esculentum*. The antioxidant activity of *F. esculentum* was high. At a concentration of 1 mg/ml, the highest antioxidant activity was reported (81.64%) [82]. Buckwheat seed components were extracted from hulls and groats and screened for antioxidant and free radical-scavenging activities using solvents of various polarities. The methanolic extract had the highest level of activity. The radical scavenging effectiveness of extracts was also found to be concentration dependent. Tocopherols were present in the hexane extract, while phenolic acids and flavonoids were abundant in the methanolic extract [83]. Similarly, catechins isolated from *Fagopyrum esculentum* had higher antioxidant activity than rutin [43]. In terms of antioxidant and radical scavenging activity, the extract of buckwheat herb was compared to rutin, which was the main constituent of the extract. The reactivity of the antioxidant activity against the 1,1-diphenyl-2-picryl-hydrazyl radical was calculated (DPPH). The extract had significantly higher antioxidant activity than pure rutin in the DPPH assay. Because of the presence of small phenolic compounds in the extract, using the extract from buckwheat herb appears to be more effective than using pure rutin [84]. Buckwheat hull extract scavenged superoxide anion produced in the xanthine/xanthine oxidase system (IC_{50}=11.4μg phenolic compound/ml) and inhibited autoxidation of linoleic acid (IC_{50}=6.2μg phenolic compound/ml). Since buckwheat hull extract significantly improved SOD activity in serum, it was found to extract healthy low-density lipoprotein oxidation caused by Cu^{2+} ion. Buckwheat hull extract has been shown to defend biological systems against oxidative stress *in-vitro* and to have antioxidant activity *in-vivo* [85]. Furthermore, buckwheat honey samples were tested for their ability to inhibit the production of reactive oxygen species (ROS) by activated human PMNs, antioxidant activity (superoxide anion scavenging in a cell-free system), and inhibition of human complement (reducing levels of ROS by limiting formation of complement factors that attract and stimulate PMNs). The majority of the honey samples were found to be active inhibitors of reactive oxygen species [86]. Likewise, the total phenolic content and antioxidant capacity of the culture and buckwheat dough matrix were assessed. There was an improvement in total phenolic content. Furthermore, fermented buckwheat's antioxidant ability included an increased percentage of 2,2-diphenyl-2-picrylhydrazyl scavenging activity and ferric decreasing antioxidant power potential [87]. Buckwheat phenolic content and antioxidant activity varied across locations, suggesting that increasing conditions and the relationship between variety and climate play an important role in determining individual phenolic and antioxidant properties. However, different processing methods, such as roasting or extrusion, had no discernible effect on the total phenolic content or antioxidant activity of buckwheat flour. Roasted (200^0C, 10 min) buckwheat flour only increased in both non-polar and polar compounds, whereas extrusion increased only in polar compounds [88]. When buckwheat flour was suspended in acidified saliva or an acidic buffer solution in the presence of nitrite, proanthocyanidins in the flour reduced nitrous acid output. The nitration and nitrosation of proanthocyanidins may contribute to the scavenging of reactive nitrogen oxide species produced by NO and nitrous acid, and the increase in NO concentration may improve the function of the stomach, assisting in the digestion of ingested foods. Both buckwheat extract and the rutin norm prevented lipid oxidation in mouse brain lipids after digestion in the stomach [89, 90]. Other parts of the buckwheat plant, in addition to the seeds, showed strong antioxidant activity [47]. Hulls, bran, and protein hydrolysates from *F. esculentum* displayed excellent antioxidant activity, including free radical scavenging activity, inhibition of lipid and linoleic acid peroxidation [91-94]. Buckwheat groats, on the other hand, have been shown to have a positive impact on protein and lipid peroxidation in rats, as well as an improved lipid profile. As per the researchers, buckwheat groats consumption may protect against dyslipidaemia by reducing plasma triglycerides and low-density lipoprotein cholesterol while improving HDL cholesterol, lowering atherogenicity indexes. Consumption of buckwheat resulted in an increase in antioxidant enzyme activities and antioxidant defence indices, resulting in improved health [95].

10.2 Antilipidemic, Hepatoprotective with Cardiovascular Ramifications

Buckwheat-rich diets have been related to a reduced risk of high cholesterol and high blood pressure. The Yi people of China eat a buckwheat-rich diet (100 grams per day). Researchers noticed that buckwheat consumption was linked to lower total serum cholesterol, lower low-density lipoprotein cholesterol (LDL-C), and a high ratio of high-density lipoproteins (HDL) in 805 *Yi Chinese*. Buckwheat also contains a lot of magnesium. This mineral relaxes blood vessels, increasing blood flow and nutrient distribution while lowering blood pressure-the ideal combination for a heart that is healthy. Moreover, buckwheat's health benefits are attributed in part to its abundance of flavonoids, especially rutin. These compounds assist in maintaining blood flow, avoiding unnecessary blood loss by preventing platelet clotting, and shielding low-density lipoprotein from free radical oxidation into potentially harmful cholesterol oxides. All of these activities aid in the prevention of heart disease. Furthermore, postmenopausal women with elevated cholesterol, high blood pressure, or other symptoms of cardiovascular disease can consume a serving of whole grains, such as buckwheat, at least six days per week [96]. Rutin and quercetin were the major phenolics contained in *F. esculentum*. Rutin relaxes smooth muscles and is useful for preventing capillary apoplexy and retinal haemorrhage, as well as reducing blood pressure and demonstrating antioxidant and lipid peroxidation efficiency. It also has a lipid-lowering effect by reducing dietary cholesterol absorption as well as plasma and hepatic cholesterol levels [79]. Buckwheat protein extract has been shown to have hypocholesterolaemia, anti-constipation, and antiobesity properties in rat feeding trials. Furthermore, buckwheat protein product decreased cell proliferation, which protected rats from 1,2-dimethyhydrazine (DMH)-induced colon carcinogenesis [97]. Likewise, buckwheat (*Fagopyrum esculentum*) intake in rats minimized numerous cardiovascular risk factors caused by obesity in laboratory rats. For four weeks, the rats were fed an obesogenic diet with buckwheat. The *F. esculentum* group had lower total cholesterol, LDL-C, and HDL levels, as well as a large aortic lumen, all of which increased cardiovascular risk factors [98]. Angiotensin II-induced hypertrophy in cultured neonatal rat cardiomyocytes was found to be inhibited by buckwheat rutin [99]. *F. esculentum* was used to isolate and classify an inhibitory peptide for the angiotensin-converting enzyme (ACE). Using a protein sequencing system and electrospray-LC–mass spectrometry, the ACE inhibitor was identified as Gly-Pro-Pro, a tripeptide with an IC_{50} value of 6.25 µg protein/ml [100]. Different peptides isolated from lactic-fermented buckwheat sprouts were recently reported to inhibit angiotensin-converting enzyme activity in rat thoracic aorta tissue and suppress angiotensin II-mediated vasoconstriction [101]. In a single-centre, randomised, double-blind, placebo-controlled clinical trial, the effectiveness of buckwheat herb tea was also determined in patients with chronic venous insufficiency, and the study documented that the treatment with buckwheat herb tea is safe and has a favourable effect on patients with chronic venous insufficiency, preventing further oedema growth [74]. In several animal models, buckwheat protein (BWP) induces hypocholesterolaemia by increasing faecal excretion of neutral and acidic sterols. The capacity of BWP to disrupt micelle cholesterol solubility through sequestration of cholesterol was investigated in the current report. Cholesterol solubility was decreased by 40% when BWP (0.2%) was incubated with cholesterol and micelle lipid components prior to micelle formation. In Caco-2 cells, the reduction in cholesterol absorption was dose-dependent, with maximal reductions at 0.1-0.4% BWP. In cholesterol-binding experiments, an insoluble BWP fraction was correlated with 83% of the cholesterol, suggesting a high cholesterol-binding potential that disrupts solubility and Caco-2 cell uptake [102]. Similarly, germinated buckwheat suppresses the gene expression of adipogenic transcription factors like PPAR gamma and C/EBP alpha in hepatocytes, resulting in potent anti-fatty liver effects. Buckwheat protein is thought to boost health in a variety of ways, including lowering serum cholesterol, preventing gallstones, cancers, and lowering triiodothyronine (T_3) levels [103-105]. Buckwheat and honey-weed supplemented diets have been found to have a positive effect on broiler chick growth rate, and treatment was found to have a strong impact on lowering health-hazardous serum total cholesterol, LDL, triacylglycerols, and elevation of serum HDL cholesterol level, as well as improving blood parameters when compared to commercial regulation [106]. After 5 weeks of treatment with both raw buckwheat extract and germinated buckwheat extract, spontaneously hypertensive rats and normotensive Wistar-Kyoto rats showed lower blood pressure and significantly reduced oxidative damage in aortic endothelial cells by reducing nitrotyrosine immunoreactivity in aortic endothelial cells [107]. In rats fed a high-fat diet, supplementation with a powdered mixture of whole buckwheat leaf and flower, which is high in phenolic compounds and fibre, tended to reduce body weight gain and lower plasma and hepatic lipid concentrations while simultaneously increasing faecal lipids [108]. Furthermore, rats fed buckwheat protein extract for three weeks had substantially lower hepatic triglyceride concentrations and weights of epididymal and perirenal fat pads. Hepatic glucose-6-phosphate dehydrogenase and fatty acid synthase activities were decreased by buckwheat protein extract, but hepatic carnitine palmitoyltransferase I activity was unaffected. Moreover, the extract increased faecal excretion of fat and nitrogen as well as both neutral and acidic steroid [109, 110].

10.3 *F. esculentum* as Cytotoxicity Emissaries

When Cellosaurus cell line H22 cells were treated with an extract of *Fagopyrum esculentum* flowers and leaves, which inhibited tumor cell proliferation and induced apoptosis [111, 112]. Conversely, by improving the immune function of H22 tumor mice, the immunosuppression induced by cyclophosphamide can be reduced [113]. Buckwheat flower and leaf can also help mice avoid developing S180 tumors by raising GSH-Px and Superoxide dismutase activity in the blood and lowering malondialdehyde levels [114]. At a concentration of 1.0 mg/mL, the ethyl acetate and butanol fractions of *F. esculentum* sprout ethanol extracts inhibited development in A549, AGS, MCF-7, Hep3B, and Colo205 cancer cell lines by 70.3%, 94.8%, 79.6%, 82.3% and 73.2%, respectively [115]. In addition, *in-vitro* recombinant buckwheat trypsin inhibitor (rBTI) had potent antiproliferative activity, and its mutant (aBTI) had even greater antiproliferative efficacy against HL-60, EC9706, and HepG2 cells, suggesting that it may be a potential cancer treatment candidate and it also inhibited HL-60 *in-vitro* [81, 116]. Buckwheat consumption was linked to a lower risk of lung cancer in a population-based case-control study [117]. Buckwheat hull ethanolic extract and its fraction also have anticancer effects against a multitude of cancer cell lines. In sarcoma-180 implanted mice, all extracts at doses of 25 and 50 mg/kg reduced tumor development by more than 20% and 42%, respectively [118]. Analogously, lapathoside A, a phenylpropanoid ester isolated from buckwheat roots, has anticancer activity in human pancreatic cancer cell lines (PANC-1 and SNU-213), and treatment with lapathoside A increased apoptosis while affecting the expression levels of apoptotic proteins [58]. Buckwheat protein diet significantly reduced cell proliferation and expression of proto-oncogene proteins in the colonic epithelium of rats with Hydrazomethane-induced colon tumors. Dietary buckwheat protein reduced the risk of colonic adenocarcinoma by 47% while having no effect on the risk of colonic adenomas [119]. Dietary buckwheat protein also slowed the development of 7,12-dimethyltetraphene-induced mammary carcinogenesis in rats [120].

10.4 The Effect of *F. esculentum* on Memory and Neurodegenerative Misery

The progressive dysfunction and loss of neuronal structure and function that results in neuronal cell death is known as neurodegeneration. Acute neurodegeneration is a disorder in which neurons are quickly weakened and die as a result of a traumatic accident or a sudden insult, such as a head injury, stroke, traumatic brain injury, cerebral or subarachnoid haemorrhage, or ischemic brain damage. Chronic neurodegeneration, on the other hand, is a long-term disease in which neurons in the nervous system undergo a neurodegenerative process that begins progressively and worsens over time due to a number of factors, resulting in the gradual and irreversible death of specific neuron populations. Alzheimer's disease, Huntington's disease, Parkinson's disease, and amyotrophic lateral sclerosis are examples of progressive neurodegenerative disorders [121]. In an *in-vitro* study, ethyl acetate and ethanol extracts of common buckwheat seeds, stems, and aerial components exhibited neuroprotective effects through inhibitory and antioxidant activities of acetylcholinesterase, butyrylcholinesterase, and tyrosinase. These findings indicate that buckwheat has neuroprotective properties. However, it should be noted that *in-vivo*, nerve cells do not encounter the entire extract. As a result, these *in-vitro* experiments do not resemble a physiological situation [122]. Seed extracts from *F. esculentum* showed significant inhibition of tyrosinase, indicating that seeds may be a promising candidate for Parkinson's disease treatment. Before clinical use, further research into the process should be conducted [123]. In addition, *F. esculentum* sprouts have a high luteolin content. Since oxidative stress and neuroinflammation are related to the onset and progression of neurodegenerative diseases, as well as neuronal cell death, the researchers found that luteolin reduced oxidative stress in neuroblastoma cells, reduced inflammation in brain tissues, and regulated various cell signalling pathways, meaning that luteolin may be used as a novel therapeutic [124-126]. The effects of buckwheat hull extract on toxicantinduced spatial memory impairment and hippocampal neuron damage in rats were also explored. The researchers concluded that supplementing foods with buckwheat hull extract improved rats' spatial memory and protected them from hippocampal neurodegeneration and spatial memory deficiency [127]. Consequently, the action of buckwheat polyphenol from *F. esculentum* in a repeated cerebral ischemia rat model indicated that buckwheat polyphenol could ameliorate spatial memory impairment by inhibiting glutamate release and delayed NO generation in rats subjected to repeated cerebral ischemia [128]. Similarly, in an eight-arm radial maze, rats consuming common buckwheat (600mg/kg) dramatically improved the spatial memory impairment caused by scopolamine. The authors exposed primary cultures of rat hippocampal neurons to buckwheat to figure out how it protects them. This extract inhibited cell damage caused by glutamate, kainite, and β-amyloid by scavenging DPPH radicals [129].

10.5 Antidiabetic Authenticity

Buckwheat seed intake was found to reduce the incidence of hypertension, dyslipidaemia, and hyperglycaemia in epidemiological studies [130, 131]. D-chiro-inositol, flavonoids, and buckwheat protein are the key antidiabetic function compounds in buckwheat [132, 133]. Buckwheat's nutrients can help regulate blood sugar levels. Buckwheat groats significantly reduced blood glucose and insulin responses in a test comparing the effect of whole buckwheat groats on blood sugar to bread made from refined wheat flour. The desire to satisfy hunger was also a strong suit for whole buckwheat’s [96]. It has historically been shown that intragastric administration of a buckwheat concentrate containing D-chiro-Inositol, myo-inositol, and fagopyritols dramatically reduced serum glucose concentrations in streptozotocin rats in the fed state. D-chiro-Inositol (DCI) is a naturally occurring isomer of inositol and is the key active nutritional component in *F. esculentum* [134]. DCI, as an epimer of myoinositol, is thought to be the primary mediator of insulin metabolism, improving insulin action while lowering blood pressure, plasma triglycerides, and glucose levels. As a result, DCI has a lot of interest as an adjunctive therapy for insulin resistance diseases like type 2 diabetes and polycystic ovary syndrome [135, 136]. Buckwheat intakes in the diet can lower blood glucose concentrations and diabetes prevalence rates, according to an experimental study. Normal and type II diabetes rats were given ethanol and water extracts of *F. esculentum* seeds, which significantly reduced blood glucose levels [137, 138]. The most bioactive constituent of *F. esculentum* flowers and leaves was rutin, which could regulate the metabolic disorder of glucose and lipids in fat emulsion and alloxan-induced diabetic rats and improve insulin resistance and possessed a protective effect on liver injury at an early stage in diabetic rats by decreasing the levels of fasting blood glucose, serum total bilirubin, alanine aminotransferase and liver index and restoring the histologica1 injury of hepatocytes [139, 140]. Furthermore, buckwheat protein decreased blood glucose in alloxan-induced diabetic mice, while pumpkin and buckwheat co-administration significantly reduced blood glucose in alloxan-induced diabetic rats [141, 142]. Buckwheat also inhibited α-amylase activity in a competitive way, suppressing postprandial hyperglycaemia in rats after starch loading. Even after digestion and heating, buckwheat maintained its inhibitory activity against α-amylase. As a result, it's a good candidate for use as a functional component in Food for Specified Health Uses, such as foods that help prevent diabetes by lowering blood glucose levels [143]. Buckwheat (*Fagopyrum esculentum*) has a proteinaceous α-AI albumin fraction that inhibits porcine pancreatic α-amylase [144]. During a six-year study of the impact of whole grains on the incidence of diabetes in Iowa, researchers discovered that women who supplemented the whole grains of *Fagopyrum esculentum* on a daily basis had a 21% lower risk of diabetes than those who ate one serving per week. Since buckwheat is high in magnesium, it's worth noting that women who consumed the most magnesium-rich foods had a 24 percent lower risk of diabetes than women who enjoyed the least [145].

10.6 Renal Repercussion

Buckwheat consumption was found to have a significant impact on the relief of diabetes and its complications in clinical trials. In type 2 diabetes mellitus rats, total flavonoids from buckwheat flowers and leaves had a substantial protective effect against kidney damage. In type 2 diabetic rats, total flavonoids from buckwheat flowers and leaves reduced fasting blood glucose, increased insulin resistance, induced creatinine clearance rate and renal morphological alterations, and down-regulated the expression of inhibiting protein tyrosine phosphatase-1B (PTP1B). This effect may be due to inhibiting PTP1B, which lowers blood glucose and reduces kidney damage [146]. Similarly, the state of oxidative stress was increased in nephrectomized rats given buckwheat extract by restoring the reduced activities of reactive oxygen species-scavenging enzymes such as superoxide dismutase and catalase. The severity of extratubular lesions like crescents and adhesions, the glomerulosclerosis index, and the severity of tubular interstitial lesions all increased as well. Furthermore, buckwheat extracts improved kidney function in nephrectomized rats, as evidenced by lower serum creatinine levels and a significant decrease in methylguanidine, a uremic toxin derived from creatinine in the presence of hydroxyl radicals [147]. The kidney injury caused by ischemia-reperfusion in rats is also improved by buckwheat extract. The extract was shown to protect cultured proximal tubule cells exposed to hypoxia-reoxygenation, most likely by prohibiting oxygen free radicals from attacking the cell membranes [148].

10.7 Anti-Inflammatory, Antinociceptive and Antipyretic Potential

Polyphenols and flavonoids abound in buckwheat. Rutin was identified as the most health-promoting antioxidant component and has also been shown to be anti-inflammatory [149]. Research studies have shown that various extracts of *Fagopyrum esculentum* are useful for treating or preventing the progression of inflammatory diseases *in-vitro* and *in-vivo*, demonstrating significant anti-inflammatory activity [31]. *In-vitro* and *in-vivo*, an ethanol extract of *F. esculentum* sprouts showed substantial anti-inflammatory activity. In mice stimulated by Lipopolysaccharide, *F. esculentum* sprouts can decrease the levels of IL-6 and TNF-. Furthermore, it had a direct impact on the expression of IL-6 and IL-8 genes in HeLa cells. *F. esculentum* sprouts, in a global perspective, could be a promising candidate for preventing the progression of various inflammatory diseases [150]. Following that, *F. esculentum* was found to be capable of reducing antigen (DNP-HSA)-induced histamine, prostaglandin D2 (PGD2), and cysteinyl Leukotriene (cysLT) release in IgE-sensitized RBL-2H3 cells. Consequently, it suppressed antigen-induced HDC2, COX-2, and 5-LO mRNA expression in IgE-sensitized RBL-2H3 cells [151]. Additionally, buckwheat was found to have antinociceptive and antipyretic properties [152].

10.8 Antimicrobial Prospective

Many bioactive compounds found in plants, herbs, and spices have been shown to have antimicrobial properties and can be used as a source of antimicrobial agents to combat foodborne pathogens. Recent research has found that the volatile oils extracted from *Fagopyrum esculentum* flowers have antimicrobial activity against seven common bacteria: *Bacillus subtilis*, *Staphylococcus aureus*, *Proteus mirabillis*, *Agrobacterium tumefaciens*, *Escherichia coli*, *Pseudomonas lachrymans* and *Xanthomonas vesicatoria* [153]. In contrast, three new fatty acids were isolated from the methanol extract of *F. esculentum* hulls, and they showed potential antimicrobial activity against *Staphylococcus aureus* and *Enterococcus faecalis* [56]. Tannins from buckwheat also showed antibacterial activity against *Listeria monocytogenes*, with MICs ranging from 62.5 to 500 microg/ml [154]. The mycelial growth of *Fusarium oxysporum* and *Mycosphaerella arachidicola* was also inhibited by buckwheat hulls extract [155]. Alternatively, malted extracts of *F. esculentum* endorse that antibacterial agent towards the food borne pathogens (*Streptococcus pyogenes, Bacillus cereus, Proteus vulgaris, Shigella sp., Klebsiella pneumoniae, and Pseudomonas aeruginosa*) and might be used as herbal components with their antimicrobial consequences in food industry [156]. Concurrently, buckwheat seed supplementation with black cumin seed suppressed pathogenic bacteria such as *E. coli* and *Salmonella sp*. According to these systematic reviews, supplementing broiler rations with 10% buckwheat seed and 1.5% black cumin seed might be an alternative to hazardous synthetic antibiotics for safe poultry production [157]. Plant defensins are antimicrobial host defence peptides expressed in all higher plants. We highlight a novel antimicrobial peptide (*Fa*-AMP1 and *Fa*-AMP2) isolated from buckwheat seeds using gel filtration, ion-exchange HPLC, and reverse-phase HPLC techniques in this review. This new category of antimicrobial peptides shared characteristics with the defensin and glycine-rich peptide families, as well as having broad antimicrobial activity. Antimicrobial peptides' unique properties as potent antimicrobial compounds suggest that they may have evolved as a sophisticated defense mechanism for protecting the plant body [158].

10.9 Additional Relevant Implementations

Fagopyrum esculentum, despite the above-mentioned activities, has a multitude of other bioactivities. The central nervous system was found to be restrained by *F. esculentum* polysaccharide, which effectively inhibited spontaneous motion, reduced the latent period of falling asleep, and prolonged the sleep time induced by sodium pentobarbital in mice [159]. Consequently, *F. esculentum* grain extract administered orally, intraperitoneally, or intradermally inhibited compound 48/80-induced vascular permeability as measured by Evans blue extravasation. Anti-dinitrophenyl IgE-stimulated passive cutaneous anaphylaxis was significantly reduced when buckwheat grain extract was given orally. Compound 48/80-induced histamine release from rat peritoneal mast cells was also inhibited by buckwheat grain extract *in-vitro*. Furthermore, buckwheat grain extract inhibited the induction of IL-4 and TNF-α mRNA in human leukemia mast cells by phorbol myristate acetate and A23187. All of these findings point to buckwheat grain extract having an anti-allergic effect in mast cells, most likely by inhibiting histamine release and cytokine gene expression [160]. According to a recent study, *F. esculentum* can be used as a nematicidal plant to combat root knot nematodes and can be integrated into pest management systems. Interestingly, a methanolic extract of the dried plant showed anthelmintic activity with EC_{50} values of 62.6 and 40.8 µg/ml after 48 and 72 hours of immersion, respectively. However, after the same time of immersion, the extract from fresh plant was less active, with EC_{50} values of 127.7 and 98.3 µg/ml, respectively [161]. The extraordinary benefits of a honeybee and *Fagopyrum esculentum* grains powder ointment in the treatment of a large dermal wound in a male rabbit accidentally injured. The ointment's beneficial effects were observed in the inflammatory phase, wound contraction stimulation, and a reduction in healing time. The ointment of honey and buckwheat, according to the report, stimulates the healing process in dermal wounds, specifically in terms of wound contraction, because it contains significant quantities of nutrients, including essential amino acids like lysine, proline, and glycine, as well as vitamin C, all of which are involved in the formation of collagen synthesis precursors [162]. Chlorophyll production, fertilization, pollen function, and germination all require zinc nanomaterials. Zinc is one of the micronutrients that affects plant susceptibility to drought stress. In the presence of zinc and zinc oxide, the plant's germination rate may be affected. Zinc oxide nanomaterials are toxic and have an impact on both chromosomal and cellular levels. For buckwheat species (*Fagopyrum esculentum*), there were obvious root germination effects due to the presence of zinc oxide [163]. Engineered nanoparticles (ENPs) play a critical role in the elicitation of medicinally valuable compounds. CuO ENPs (2000 and 4000 mg/L) exposure, on the other hand, resulted in a decrease in buckwheat root growth [164]. Buckwheat, in particular, is a metal hyperaccumulator that efficiently transports metals from roots to shoots [165]. The prevalence of skin cancer has increased dramatically in recent years. Sunlight, particularly ultraviolet radiation, is thought to be a key factor in the development of skin cancer. As a result, there is a growing interest in developing UV-protective compounds for use in sun care products. Topical application of herbal antioxidants is one method. A commercial UV absorber was compared to the photoprotective properties of buckwheat herb extract. The inhibition of photosensitized lipid peroxidation of linolic acid was used to test the photoprotective properties of buckwheat extract. The extract was more effective than rutin or a commercial UV absorber at preventing linolic acid peroxidation caused by UV light. Because of the presence of minor phenolic compounds in the extract, using the extract from buckwheat herb was more useful than using pure rutin [84]. Furthermore, various buckwheat-derived products have been documented and shown to have health benefits, including prebiotic, antifatigue, immunomodulation, leg oedema protection, and stomach activity improvement [10, 166, 167]. Silver nanoparticles stabilized by *Fagopyrum esculentum* starch have been reported as a promising antimicrobial agent against bacteria and fungi. The nanoparticles inhibited Gram-negative bacteria (*Escherichia coli*) more effectively than Gram-positive bacteria (*Staphylococcus aureus*) [168]. In addition, *F. esculentum* leaf extract also aids in the green synthesis of biocompatible gold nanoparticles, suggesting that organic biomolecules on the surface of the gold nanoparticles have cytotoxicity activity against human HeLa, MCF-7, and IMR-32 cancer cell lines. The gold nanoparticles were also found to be non-toxic and have potential for use in a variety of biomedical applications [169]. The effect of copper and silver nanoparticles on somatic cells of *Fagopyrum esculentu*m was recently studied. It was concluded that copper nanoparticles are more cytotoxic than silver nanoparticles based on the findings. At the same time, lower concentration of nanoparticles are beneficial to plants, while higher concentrations cause chromosomal aberrations [170].

11. CONCLUSION AND EXPECTATION FOR THE FUTURE

Although it's an underutilized crop, common buckwheat (*Fagopyrum esculentum*) has numerous benefits for both growers and consumers. Because of its short growing season, it is often grown in areas with a short frost-free duration or as a fall crop. It can also be planted after the first crop fails due to environmental or other factors and still achieve acceptable yields. *F. esculentum*, with its high lysine content, is a highly desirable crop in areas where transportation and protein sources are scarce. A healthy amino acid profile can be achieved by combining it with cereal grains that are low in lysine. Because this is a highly beneficial trait of the species, few crop development efforts have concentrated on growing lysine or other amino acid content. In some collections, the amino acid content of accessions has been evaluated, but no evaluation of related species has been done to date. It's possible that there's a lot of diversity out there that could be used to help the species grow. We summarized the current phytochemical and pharmacological research on *Fagopyrum esculentum* in this chapter. Modern pharmacological studies have validated almost all of their common applications, focusing on their anti-tumor, antioxidant, antiinflammatory, hepatoprotective, antidiabetic, antibacterial, antiallergic, antifatigue, and other activities. A large number of studies on the chemical profile of these *Fagopyrum esculentum* have been conducted due to their flexible pharmacological properties. Flavonoids, phenolics, fagopyritols, triterpenoids, steroids, and fatty acids were among the compounds isolated and described. Flavonoids and phenolic compounds were thought to be the most active elements, responsible for the majority of their functions. There are few published reports on therapeutic effectiveness, toxicity, or side effects of *Fagopyrum esculentum* and its constituents due to a lack of clinical trials. To confirm the effectiveness and safety, large-scale, well-controlled, and double-blind clinical trials are urgently required. Better descriptions of the mechanisms of action of various extracts and compounds are needed, as well as a demonstration of the potential interactions between bioactive constituents and synthetic drugs. Consequently, before these bioactive compounds are used in clinical practice, the structure–activity relationship and potential synergistic effect among them must be fully understood. Future research should also focus on epidemiological studies and the consolidation of mechanisms of action, especially in humans. These studies would provide a useful framework for incorporating this pseudocereal into the development of novel and nutritious foods, as well as increasing its use.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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