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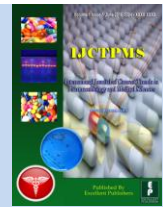

Review Article

Buckwheat (*Fagopyrum esculentum*) as a Functional Food: A Nutraceutical Pseudocereal

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Abstract

Due to the high nutritive and medicinal value, common buckwheat (*Fagopyrum esculentum*) has engrossed increasing attention from food scientists, medical scientists and pharmaceutical industries for its therapeutic effects over chronic diseases. Common Buckwheat popularly known as mithe fapar is one of the staple food crops of the mountain region. The germinated seeds or sprouts are nutritionally superior to their original seeds with higher levels of nutrients, lower amounts of compounds that interfere with the absorption of nutrients and increased protein and starch digestibility. Starch metabolism in developing as well as geminating seeds and experiments with animal models have demonstrated that buckwheat and its nutrients inside may alleviate diabetes, obesity, hypertension, hypercholesterolemia, polycystic ovary syndrome, constipation, bowel upsets, obesity and several other diseases. In recent years, buckwheat has regained interest as an alternative crop for organic cultivation and as a health food because of its high nutritious value. But, the cultivation of buckwheat has decreased over the last century which provides a base of information for enhancing buckwheat production and management in the short and long term research enhancement especially in the area of cultivar improvement, pharmaceutical and medicinal applications. Therefore, in this review we analyzed the important nutraceutical properties, various components of buckwheat and their impact on health and diseases which can be used for medical benefits of general health of people and for drug discovery in pharmaceuticals.

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Introduction

Buckwheat (*Fagopyrum esculentum*) is a pseudocereal which belongs to the Polygonaceae family. Despite the common name and the grain-like use of the crop, buckwheat is not a cereal or grass. It is ubiquitous almost everywhere, but grows mainly in the northern hemisphere. Originating from Asia and introduced into Europe around the 15th century, the cultivation of buckwheat has spread to Canada, the United States of America and to certain areas of Africa and Latin America, mountains of Nepal, Bhutan and India growing at high altitudes above 3, 000 meters (Li and Zhang, 2001). Buckwheat grain is characterized by a high content of starch, protein with an advantageous amino acid composition, a low content of α-gliadin and a high content of dietary fibre (Dziedzic et al., 2012). Seeds of buckwheat are one of the best sources of high quality, easily digestible, glutenless food and rich in potassium, phosphorous, calcium, iron, zinc, vitamins B, E, and rutin (Dietrych-Szostak, 2006). Additionally, extracts from buckwheat flour show anti-mutagenic activity, provide protection from oxidative stresses, and have the potential to improve diabetes symptoms (Inglett et al., 2010).

Healthiness of buckwheat has been endorsed to the content of several natural antioxidants including tocopherols, phenolic acids, and flavonoids (Dietrych-Szostak and Oleszek, 2011). Distinctively buckwheat can be used in the production of foods for people with celiac disease, for those subjects who suffer from gluten intolerance, typhoid and liver ailments. It is the only pseudocereal that contains rutin and it is a beneficial source of this flavonoid. Other phenolic compounds and flavones such as hyperin, quercitrin, and quercetin have been detected and isolated from immature buckwheat seeds (Koyama et al., 2013). They acquire special medicinal properties such as anti-hypertensive and anti-hypercholesterolemic effects at nontoxic concentrations in humans (Li et al., 2010; Prakash and Deshwal, 2013). Buckwheat protein shows high biological value due to a well-balanced amino acid pattern and is rich in lysine and arginine and has many unique physiological functions, such as curing chronic human diseases, decreasing blood cholesterol, inhibiting mammary cancer caused by 7, 12-dimethylbenzene, restraining and suppressing gallstone, tumors and inhibiting the angiotensin I-converting enzyme so on (Prakash et al., 2015; Tomotake et al., 2006, 2000; Prakash and Deshwal, 2013).

Much progress has been made in improving the nutrition and healing effects of buckwheat as a functional food in the last few years. In humans, the consumption of buckwheat is associated with a lower prevalence of hyperglycemia and improved glucose tolerance in people with diabetes (Zhang et al., 2007). The main phenolics of buckwheat extract were rutin, quercitrin, and quercetin. Rutin (quercetin-3-O-β-rutinoside) is the best-known glycoside derived from flavonol quercetin, which has relaxing effects on smooth muscles and is effective for preventing capillary apoplexy and retinal hemorrhage, reduce high blood pressure, and show antioxidant and lipid peroxidation activities. It also has a lipid-lowering activity by decreasing the absorption of dietary cholesterol as well as lowering plasma and hepatic cholesterol (Jiang 2007; Prakash et al., 2015).

D-Chiro-inositol (DCI) is the main active nutritional ingredient in buckwheat. DCI is probably the main mediator of insulin metabolism by enhancing the action of insulin and decreasing blood pressure, plasma triglycerides and glucose concentrations (Prakash et al., 2015; Fonteles et al., 2000; Ueda et al., 2005). Buckwheat was found to have high levels of angiotensin I-converting enzyme (ACE)-inhibitory activity. ACE converts angiotensin I to II, which is a pressor hormone in the renin-angiotensin (RA) blood pressure control system (Higasa et al., 2011). High levels of vitamin E intake have been associated with a reduction in cardiovascular disease, lowering the risk of Alzheimer's disease and prostate cancer, improving the immune system, and delaying both age-related cataracts and age related macular degeneration which has been found predominant in buckwheat (Kalinova et al., 2006).

Another important phenomenon occurring in buckwheat is germination which makes the buckwheat more nutraceutical, pharmaceutical and medicinal. Germination is a complex process in which significant changes in the biochemical, nutritional and sensory characteristics occur due to the activation of dormant enzymes (Asian Scientist, 2015). Starch is the most common reserve carbohydrate in seeds and an important commercial source is the endosperm of cereals. Both α-amylase and β-amylase are present in seeds; β-amylase is present in an inactive form prior to germination, whereas α-amylase and proteases appear once germination has begun. As a result, the germinated seeds or sprouts are nutritionally superior to their original seeds with higher levels of nutrients, lower amounts of compounds that interfere with the absorption of nutrients and increased protein and starch digestibility (Zhang et al., 2015). Germinated buckwheat is an important raw material for food and functional food production which has better nutritional value than ungerminated buckwheat. The germinated seeds could help in the prevention and treatment of various human diseases and also be helpful in improving the development of active components for functional food products and in pharmaceuticals (Mazza and Oomah, 2005).

But, the cultivation of buckwheat has decreased over the last century. The main reason for this decline was self-incompatibility, which lead to breeding difficulties. Buckwheat has been renewed as an alternative crop for organic cultivation and as a health food (Li and Zhang, 2001; Biacs et al., 2002; Pomeranz, 1983; Ikeda, 2002). This provides a base of information for enhancing buckwheat management in the short term, while simultaneously determining avenues for long term research enhancement, especially in the area of cultivar improvement, pharmaceutical and medicinal applications. Therefore, in this review article we analysed the nutraceutical properties of common buckwheat which can be a beneficiary tool for the recovery of certain diseases in medical sciences and for drug discovery in the pharmaceuticals.

General morphology of buckwheat

The Polygonaceae family has leaves that vary in size, arrangement and shape, but the leaf stalk is always surrounded by a membranous or chaffy sheath at the base. The flowers are often grouped in clusters that are showy owing to the colour of the sepals or bracts, for there are no petals. This species is dimorphic, having plants bearing one of two flower types. The pin flowers have long pistils and short stamens while the thrum flowers have short pistils and long stamens. Two sizes of pollen are associated with the heteromorphic system. Large pollen grains approximately 0.16 mm in diameter are produced by thrum flowers while pin flowers produce smaller pollen grains that are approximately 0.10 mm in diameter (Biacs et al., 2002).

The fruit is a triangular nut, sometimes prominently winged. The common buckwheat plant is a broad leaved, erect, annual with a single main stem and a branching habit. The main stem is grooved, succulent and smooth except at the nodes. The plants generally grow to 0.6-1.3 m tall. The stems are hollow and therefore are subject to breakage by high winds. They are also subject to breakage due to hail as they snap off where struck. They can recover from hail damage by branching from lower leaf axils if the hail occurs when the plants are relatively immature. The plants have a short taproot and fine lateral roots producing a root system that is about 3-4% of the weight of the total plant. The plants can therefore suffer from extreme drought conditions which usually results in delayed maturity.

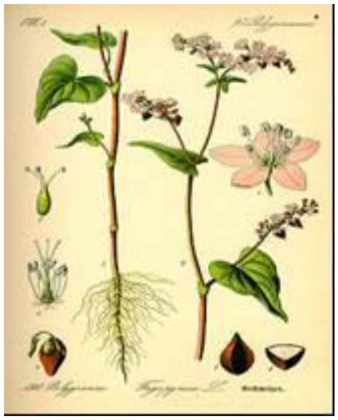


Fig. 1: Common buckwheat.

Prior to maturity, the stems and branches vary from green to red. They become reddish brown at maturity (Mazza and Oomah, 2005). The embryo in a buckwheat seed is located in the centre of the endosperm and possesses two cotyledons. The hull (pericarp) has a hard fibrous structure and surrounds the seed coat, endosperm, and embryo tightly. The endosperm cells have thin cell walls and consist mainly of starch (Pomeranz, 1983; Steadman et al., 2000). Buckwheat seeds are edible and have a nonstarchy aleurone layer (Bonafaccia et al., 2003).

Fig. 2: Seeds of different Buckwheat (*Fagopyrum esculentum*) varieties.

Types of buckwheat

There are three types of buckwheat: *cymosum* (wild), *tartaricum* (tartary) and *esculentum* (common).

Fagopyrum tataricum

This is an annual herb, up to 1 m tall, branched or unbranched with stem, which is striate, always having papillate on branchlet. Leaves are petiolate, most blades are triangular, width equals length, 2-8 cm and bases are cordate or hastate. Inflorescences are dense spicate or corymbose. Flowers are yellow-green, 2.5 mm in diameter, pedicels are nonparticulate; perianths are 2 mm long; 8 nectaries are yellow, alternating with stamens being homostyly, stigmas are capitate**.**

Fig. 3: *Fagopyrum tataricum.*

Triquetrous achene is about 5 mm long, exerting more than twice the length of the persistent perianths, with three deep grooves and the angles are rounded, except at the tip. This species is now cultivated in the high-altitude mountainous areas of Asia and to a much lesser extent elsewhere. It has many cultivars or landraces. Its ache forms and sizes differ greatly; some of them are winged or spinous on the angles and some with hulls that split between the angles on maturity. The plants of *F. tataricum* are usually less husky in growth and are more branched and the leaves are more arrows shaped. The flowers are smaller having inconspicuous greenish-white sepals and do not appear to be attractive to insects. The flowers are homomorphic, self-fertile and are cleistogamous with pollination occurring before the flower opens (Pomeranz 1983; Onishi 1996).

Fagopyrum esculentum Moench

This is an annual herb, up to 1 m tall, branched and glabrous. Leaves are petiolate, blades are ovate-triangular to triangular, 2-8 cm long, with acuminate tips, bases are cordate or approximately hastate, upper leaves are smaller and sessile. Inflorescences are terminal and auxiliary, branch in dense corymbose or paniculate cyme. Flowers are white or pink, 6 mm in diameter, pedicel is 2-3 mm long, articulate, perianths are 3 mm long, 8 nectaries are yellow, alternating with stamens being heterostyly and capitate stigma. Achene is triquetrous, acute angle, longer than 5 mm, more than twice the length of the persistent perianths, brown or black-brown, lucid. Their achene forms can vary greatly, some of them being winged on the angles. This species is common buckwheat and is widely cultivated over the northern and to some extent the southern hemisphere (Biacs et al., 2002).

Fig. 4: *Fagopyrum esculentum.*

Fagopyrum cymosum

It is tetraploid perennial buckwheat that grows wild in temperate Himalayas and is commonly found around habitation areas and farms. It is utilised in certain regions as forage and also as a medicinal plant. This species extends its distribution southward to the northern part of Indochinese Peninsula, Southern part of china, and west ward to Himalayan region of Nepal and India as far as Karakoram and the Hindukush. It is also found in eastern part of Tibet. The flowering pattern resembles that of *F. esculentum* in that both are heterostylous outcrossing species and produce pin and thrum plants with white flowers. *F. cymosum*, is however, cytologically and morphologically distinct and stands out as a separate taxon (Kim et al., 2002).

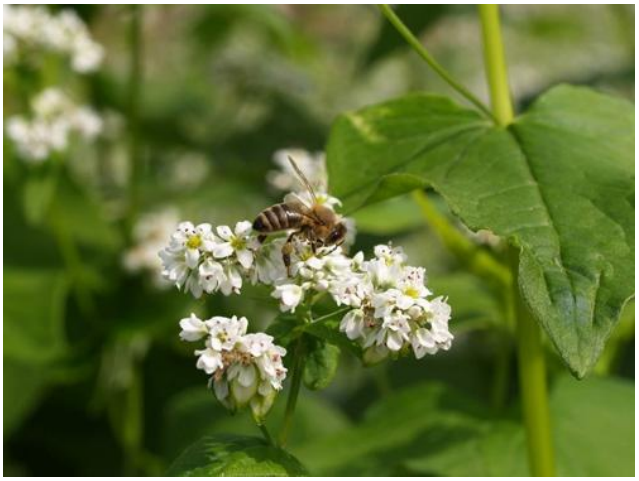


Fig. 5: *Fagopyrum cymosum.*

Geographical distribution and scientific classification of buckwheat

Buckwheat, native to temperate East Asia, where it was grown in China before 1000 AD (Krkoškova and Mrazova, 2005) is adapted in many areas of the world. Although buckwheat production is concentrated in China, Japan, and North America, it is also produced in Europe, India, Nepal, Tibet, Tasmania, Australia, Argentina, Bhutan, and numerous other countries (Joshi and Paroda, 1991).

The name "buckwheat" comes from the Anglo-Saxon words *boc* (beech) and *whoet* (wheat), because the seed resembles a small beech nut. Buckwheat seeds are the fruits (matured ovaries) of the plant. The indehiscent fruit (seed) is an achene because the three sided pericarp (hull) encloses only one true seed**.** Until recently, only two cultivated and seven wild species of buckwheat were believed to exist. However, seed collection and classification by Onishi (1996) has resulted in a total of 14 species of buckwheat, with new discoveries occurring every year.

The genetic origins of buckwheat are believed to occur in the Yunnan and Sichuan provinces of China (Onishi and Matsuoka, 1996). The recent discoveries of new wild species have provided valuable genetic material for advancing cultivar development. The most notable of these discoveries is *Fagopyrum homotropicum*. This species is self pollinated and has many characteristics similar to *F. esculentum*, thus allowing plant breeders to improve and develop new varieties with desirable production and consumption characteristics (Campbell, 1997).

Table 1. Scientific classification of common buckwheat.

Scientific classification	
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Caryophyllales
Family	Polygonaceae
Genus	*Fagopyrum*
Species	*F. esculentum*

Chemical composition of buckwheat

Sugars

The monosaccharides, glucose and fructose are mostly in the pericarp and seed coat of buckwheat. Sucrose is the major sugar accumulating in buckwheat achenes but levels of glucose and fructose are similar. Except in embryo tissues, increasing glucose and fructose levels precede sucrose and starch accumulation (Dorel, 1971). Increases in sucrose accumulation reflect periods of dry weight, increases with the embryo tissues accumulating the largest amount of sucrose. Sucrose is abundant in the seed coat and nucellus tissues and then accumulates in the developing embryo. The high concentration of sucrose in embryo tissues is typical of oil seed tissues (Duffus and Binnie, 1990). The starchy endosperm accumulates only low transitory levels of sucrose. The ovular maternal tissues (integuments and nucellus) accumulate sucrose before major accumulation of dry matter in the endosperm and embryo, and then, the sucrose level declines consistent with an apparent transport role to the developing endosperm and embryo (Kim et al., 2002). After seed set, faster-growing achenes have higher starch levels and lower sugar levels while slower-growing achenes have lower starch levels and higher sugar levels (Dua et al., 1991).

D-chiro-inositol

D-chiro-inositol is an inositol isomer that occurs in relatively high levels in buckwheat seeds (Steadman et al., 2000). Levels of inositol are low in all tissues. Inositol is detected sequentially in the pericarp, seed coat and nucellus, endosperm, and embryo during later developmental stages of buckwheat. Fagopyritols are galactosyl derivatives of D-chiro-inositol that can accumulate in seeds of some species. Buckwheat embryos are unique because they accumulate galactosyl cyclitols and not raffinose oligosaccharides (Horbowicz et al., 1992). The structures of D-*chiro*-inositol are fagopyritol B1, B2 and B3. The effects of D-chiro-inositol and fagopyritols in natural buckwheat concentrate on plasma glucose levels in humans having positive effects for patients with diabetes. Tartary buckwheat contained 50% of the level of fagopyritols and malting is one possibility to increase fagopyritol levels (Steadman et al., 2000; Horbowicz et al., 1992).

Starch

Buckwheat starch has its own unique characteristics; some properties correspond to tuber starches (high viscosity values) and others correspond more with cereal starches (shape and composition). Buckwheat starch has a high level of crude fat and amylase. Buckwheat starch granule sizes are 2.9–9.3 μm with a mean size of 5.8 μm and are round or polygonical shaped (Li et al., 1997). The appearance of a buckwheat starch granule is smooth with a few pores, possibly caused by enzymatic attack (Li et al., 1997). Due to the presence of pores and the small starch granule size, buckwheat starch is more susceptible to porcine α-amylase than are corn and wheat starch (Qian et al., 1998). The amylopectins of buckwheat contain a higher level of long chains than cereal amylopectins.

Amylases in starch

Cereal amylases have gained importance due to their suitability for biotechnological applications in supplementary foods, breweries and starch saccharification (Mazza, 1993). Cereal α-amylases play a very important role in the starch metabolism in developing as well as germinating cereals. These highly expressed enzymes are getting synthesized under the influence of plant growth hormones such as gibberellic acid (GA3) and they exist in multiple forms (MacGregor, 1952). Cereal amylases are separable into two groups based on their chemical, physical and immunochemical properties. The site of amylase synthesis is reported to be either in aleurone layer or scutellum. The starch degrading amylolytic enzymes have a great commercial value in biotechnological applications ranging from food, fermentation, textile to paper industries (Bewly and Black, 1985).

Cereal grain amylase is keys to the production of malt. Many microbes also produce amylase to degrade extracellular starches. Animal tissues do not contain β-amylase, although it may be present in microorganisms contained within the digestive tract. Certain enzyme activities should also be logical criteria for the selection of superior cultivars because synthesis of all enzymes is under genetic control and some enzymes regulates the rate of metabolism.

α-Amylase

Amylases are classified on the break down basis of characteristics of starch or glycogen molecule. α-amylases (EC 3.2.1.1), hydrolysis the internal α-1,4 linkage in starch in a random fashion leading to the formation of soluble maltodextrins, maltose, and glucose. Most of the α-Amylase is metallo-enzymes, which require calcium ions (Ca.sup.2+) for their activity, structural integrity, and stability. Alpha amylase and proteases appear once the germination begins and is synthesised *de novo* through the mediation of embryo (Maccagnan et al., 2005).

β-Amylase: β-amylase ((EC 3.2.1.2) is synthesized by bacteria, fungi, and plants which catalyzes the hydrolysis of the second α-1,4 glycosidic bond, cleaving off two glucose units (maltose) at a time. During the ripening of fruit, β-amylase breaks starch into maltose, resulting in the sweet flavor of ripe fruit. Beta amylase is present in seed in inactive form prior to germination and seedling development (Maccagnan et al., 2005).

γ-Amylase: γ-amylase (EC 3.2.1.3) cleaves the last α-(1-4) glycosidic_linkages at the non reducing end of amylose and amylopectin, yielding glucose and cleaves α-(1-6) glycosidic linkages. γ-amylase is most efficient in acidic environments and has an optimum pH of 3 (Maccagnan et al., 2005).

Resistant starch

Starch can be divided into three groups depending on the rate and extent of digestion in vitro: rapidly digestible starch, slowly digestible starch, and resistant starch (RS). RS is divided into three groups: physically inaccessible starch, native granular starch, and retrograded starch (Englyst et al., 1992). Various factors such as physical form of starch, extent of retrogradation, amylase to amylopectin ratio, and non- starchy inhibitory components affect the digestibility of starch (Skrabanja et al., 2001). Undigested starch may result in positive nutritional effects (Skrabanja et al., 2001, 2004). Foods with higher levels of resistant starch usually have a low GI and are generally advantageous for most healthy adults in improving diabetic control and can be ranked according to their blood glucose raising potential i.e. glycemic index (Skrabanja et al., 2001). Buckwheat flour extract contains compounds such as tannins, phytic acid and proteinaceous inhibitors that can act against human saliva amylase and affect the level of digestible starch. In raw buckwheat groats with a total starch content of 73.5%, 33.5% was RS (Skrabanja et al., 2004).

Lipids

Lipids comprise a small part of cereals and pseudocereals having an important physiological role in food quality as they may cause deterioration of stored seeds or flours (Chapkin, 2000). In both common and tartary buckwheat, lipids are concentrated in the embryo which contains an average of 6.5% oil, while the endosperm contains <0.4% oil (Dorrell, 1971).

Buckwheat also holds lipase activity. The lipase is a triacylglycerol lipase which shows an optimal temperature of 30°C. It consists of two isozymes: LIP I that holds a lower activity (0.108 μmol of fatty acid released/min/mg of protein at 30°C using triolein as substrate) than LIP II (0.727 μmol of fatty acid released/min/mg of protein at 30°C using triolein as substrate) (Suzuki et al., 2004). Eighteen fatty acids have been identified in buckwheat, of which 14 appear in all seed tissues. The eight main acids (oleic, linoleic, palmitic, linolenic, lignoceric, stearic, behenic, and arachidic) represent 93% of total fatty acids (Dorrell, 1971). The embryo contains most of the unsaturated fatty acids (Dorrell 1971). Some fatty acids such as linoleic acid and linolenic acid are polyunsaturated and these essential fatty acids cannot be produced by the human body (Chapkin, 2000). One of these essential fatty acids i.e. linoleic acid is the major fatty acid present in buckwheat and the level of linoleic acid is particularly high in the seed coat (Dorrell, 1971; Taira et al., 1986; Mazza, 1988). Levels of some fatty acids can be increased by germination (Kim et al., 2002).

Aminoacids

The majority of buckwheat proteins consist of globulins and albumins; buckwheat protein contains a wide range of various amino acids but contains very little or no prolamins (Pomeranz and Robbins 1972). Buckwheat protein has a high level of lysine (6.1% of 100 g of amino acid recovered), arginine (9.7%), aspartic acid (11.3%) and low levels of proline (3.9%) and glutamic acid (18.6%) (Pomeranz and Robbins, 1972).

Table 2. Average amino acid concentrations in buckwheat.

Amino acid	In seed	In groat	In protein	Amino acid	In seed	In groat	In protein
%				%			
Glumtamic acid	1.99	2.72	18.02	Alanine	0.45	0.61	4.03
Arginine	1.47	2.01	13.27	Threonine	0.43	0.58	3.87
Aspartic acid	1.20	1.64	10.86	Proline	0.41	0.55	3.66
Valine	0.85	1.17	7.71	Isoleucine	0.39	0.53	3.48
Leucine	0.75	1.02	6.75	Tyrosine	0.23	0.32	2.12
Lysine	0.66	0.90	5.99	Histidine	0.23	0.32	2.11
Glycine	0.61	0.83	5.52	Cysteine	0.18	0.25	1.66
Phenylalanine	0.46	0.63	4.17	Methionine	0.15	0.21	1.37
Serine	0.46	0.62	4.12	Tryptophan	0.14	0.19	1.29

Source: Robinson (1980)

Storage proteins

Globulins are the major storage proteins mainly found in buckwheat. During germination, storage material of protein bodies is degraded and the embryonic axis is supplied with amino acids, phosphorous compounds, and inorganic cations. Activities of proteases are under control by a number of factors: protein inhibitors, concentration of bivalent metal ions, pH, concentration of products of proteolysis and abscisic acid (Belozersky and Dunaevsky, 1999). The major storage proteins, globulins consist of two major families that differ in molecular weight (MW) and sediment with different sedimentation coefficients (S values) of ≈7 (average 7–8) and 11 (11–13) during ultracentrifugation. Both are composed of regularly assembled subunits. In buckwheat, 13S globulin and 8S globulin have been identified (Bewley and Black, 1985).

The 13S protein is a legumin like storage protein with molecular weight 2, 80,000 was found only in the cotyledons contributes to 33% of total seed proteins in buckwheat , while 8S globulin is similar to vicilin-like storage proteins found in both cotyledons and the endosperm contributes to ±7% of total seed proteins in buckwheat (Milisavljevic et al., 2004; Radovic et al., 1996). In addition to globulins, 2S albumins are water-soluble proteins with single-chain polypeptides with MW 8,000 to 16,000 are also identified in buckwheat (Radovic et al., 1996). Common buckwheat seeds consist of 64.5% globulin, 12.5% albumin, 8.0% glutelin and a small percentage of prolamins (2.9%) (Radovic et al., 1999; Ikeda, 2002).

Fibres

Dietary fibre (DF) is potentially protective against certain diseases. DF can be divided in insoluble dietary fibre (IDF) and soluble dietary fibre (SDF). IDF generally includes lignin and cellulose, while SDF includes pectin and gums whereas SDF especially may contribute positively to human health by reducing levels of blood cholesterol (Steadman et al., 2000). In addition, DF can also have a negative role as it may bind proteins and minerals, inhibit digestive enzymes, and thereby lower digestibility or absorption (Ikeda, 2002; Steadman et al., 2000). Buckwheat seeds contains DF of 27.38% which is mainly present in outer seed coverings such as the seed coat and hull (Bonafaccia et al., 2003) whereas the much lower DF percentage of ≈7% in buckwheat groats (Steadman et al., 2000; Bonafaccia et al., 2003). IDF and SDF of buckwheat groats are similar to cereals such as oats and wheat.

Minerals

Minerals are important for various physiological functions in the human body. The human body requires more than 100 mg per day of each major mineral (Na, Mg, K, Ca, P, S, and Cl) and less than 100 mg per day of trace elements (Cr, Mn, Fe, Co, Cu, Zn, Se, Mo, and I). Buckwheat is a richer mineral source (except for Ca) than many cereals such as rice, sorghum, millet, and maize. Especially, the levels of Mg, Zn, K, P, Cu and Mn are high in buckwheat when compared with other cereals (Mazza, 1988; Steadman et al., 2000). Mg, Zn, K, P and Co is mainly stored as phytate in protein bodies (Elpidina et al., 1990; Steadman, 2000). During germination, phytin is hydrolyzed and metal ions are dissolved (Bewley and Black, 1985). Buckwheat contains 10.0 mg/g of phytic acid and the enzyme phytase that liberates 2.17 μmol of inorganic phosphate/min/g (Englyst et al., 1990). Protein bodies (and therefore Mg, Zn, K, P, and Co) are generally present in embryo tissues and the aleurone layer (Steadman, 2000). Minerals such as Fe, Zn, Mn, Cu, Mo, Ni, and Al are primarily localized in both hull and seed coat. Ca and B are present in hull fractions (Steadman et al., 2000; Bonafaccia et al., 2003; Skrabanja et al., 2004). One possibility to increase mineral levels of buckwheat seeds is to germinate them in solutions with elevated mineral levels (Lintschinger et al., 1997).

Table 3. Chemical composition of buckwheat.

Parts	Parameters	Chemical compositions
Seeds	Starch	71–78% in groats, 70–91% in different types of flour starch is 25% amylose and 75% amylopectin. Depending on hydrothermal treatment buckwheat groats contain 7–37% of resistant starch.
	Proteins	18% with biological values above 90% is can be explained by a high concentration of all essential amino acids, especially lysine, threonine, tryptophan, and the sulphur-containing amino acid.
	Minerals	Rich in iron (60–100 ppm), zinc (20–30 ppm) and selenium (20–50 ppb).
	Antioxidants	10–200 ppm of rutin and 0.1–2% of tannins.
	Aromatic compounds	Salicylaldehyde (2-hydroxybenzaldehyde) was identified as a characteristic component of buckwheat aroma, (E,E)-2,4-decadienal, phenylacetaldehyde, 2-methoxy-4-vinylphenol, (E)-2-nonenal, decanal and hexanal also contribute to its aroma. They all have odour activity value more than 50, but aroma of these substances in isolated state does not resemble buckwheat.
Herb	Antioxidants	1–10% rutin and 1–10% tannins.
	Fagopyrin	0.4 to 0.6 mg/g of fagopyrins (at least 3 similar substances).

Source: FAO (1990).

Phytochemicals

Phytochemicals are plant substances that may promote good health but are not essential for life. Oxidative stress which releases free oxygen radicals in the body has been implicated in a number of disorders including cardiovascular malfunction, cataracts, cancers and rheumatism. Phytochemicals present in fruits and vegetables can act as antioxidants by scavenging free radicals and saving the cell (Kreft et al., 1996).

Flavonoids

Flavonoids are ubiquitous in most plants and usually exist in glycosidic forms (Rice-Evans et al., 1997). More recently, polyphenolic compounds such as flavonoids have received interest due to their antioxidant effect and widely known antioxidants are vitamins A, C and E. Rutin and quercetin are the main polyphenols with antioxidant activity present in buckwheat (Oomah and Mazza, 1996; Kreft et al., 1996; Steadman et al., 2000). Quercetin shows a higher antioxidant activity than rutin, which is a glycoside of quercetin . It is generally known that glycolization reduces antioxidant activities (Rice-Evans et al., 1997). Rutin and quercetin levels in buckwheat depend greatly on growth location and cultivar (Oomah and Mazza, 1996; Steadman et al., 2000).

In common buckwheat groats, levels of rutin and quercetin are ≈0.20 mg/g and 0.001 mg/g respectively. Buckwheat hulls contained higher levels of rutin (0.84–4.41 mg/g) and quercetin (0.009–0.029 mg/g) (Oomah and Mazza 1996). Tartary buckwheat is an excellent source of rutin because groats of tartary buckwheat showed levels of rutin at 80.94 mg/g. Besides rutin and quercetin, four catechins with antioxidant activity from ethanol extracts from buckwheat groats (*F. esculentum* Moench cv Iwate zairai): epicatechin, catechin 7-O-β-D-glucopyranoside, epicatechin 3-*O*-*p*-hydroxybenzoate, and epicatchin 3-*O*-(3, 4-di-*O*-methyl)- gallate (Watanabe, 1998). Catechins show a higher antioxidant activity than rutin. But both rutin and quercetin have another advantage in addition to their antioxidant activity and can help with treatment of chronic venous insufficiency (Watanabe, 1998).

Effect of buckwheat flavonoids

Flavonoid glycosides are usually hydrolyzed by intestinal microorganisms (Rice-Evans et al., 1997). *Eubacterium ramulus* is a gut bacterium that has been proved to degrade flavonoids from buckwheat. Dietary flavonoids from buckwheat leaves act as a better substrate for *E. ramulus* than pure rutin (Prakash et al., 2015). Several glucuronides have been identified as quercetin metabolites in human blood. These potentially active glucuronides are identical regardless of the type of quercetin glycosides administered (Graefe et al., 2001). Buckwheat plant extract showed better effects than pure rutin: the level of potentially bioactive quercetin metabolites in plasma was 1.33 times higher when buckwheat plant extract was administered to humans (Graefe et al., 2001).

Boyle et al. (2000) revealed that by supplementing quercetin, total quercetin levels in plasma of humans were elevated but the antioxidant status of the blood plasma was not affected. On the other hand, serum antioxidant capacity increased significantly by 7% when 25 healthy men were administered with buckwheat honey, a natural product of buckwheat (Wijngaard et al., 2005).

Vitamins

Vitamins are a group of organic compounds that are essential in very small amounts for the normal functioning of the human body. They vary widely in their chemical and physiological functions and are broadly distributed in natural food sources (Belozersky et al., 1999). Thiamine (vitamin B1) is known to be strongly adhered to thiamine-binding proteins in buckwheat seeds and its bioavailability is uncertain. In general, tartary buckwheat has higher levels of vitamin B than in common buckwheat (Bonafaccia et al., 2003).

Levels of vitamin C and the sum of vitamin B1 and B6 can be increased by germinating buckwheat. The level of vitamin C can increase up to 25 mg/100 g in buckwheat sprouts (Lintschinger et al., 1997; Kim et al., 2004). Vitamin E includes all naturally occurring tocopherols and tocotrienols but, no tocotrienols have been detected in buckwheat (Zielinski et al., 2001). Tocopherols are naturally occurring antioxidants (Dietrych- Szostak and Oleszek 1999) and exist in α-, β- γ- and δ- form (Burton and Traber, 1990). Differences have been attributed to different cultivars of common buckwheat Zielinski et al., 2001; Kim et al., 2002). Tartary buckwheat contains higher levels of tocopherols than common buckwheat (Kim et al., 2002).

Inhibitors

The poor digestibility of buckwheat protein is due to two factors: various susceptibility of proteolytic action of buckwheat fractions, and anti nutritional components such as tannins and inhibitors (Ikeda et al., 1991). The presence of proteinase inhibitors in seeds is not completely understood but can include three functions.

1) Storage: In some cereals, trypsin inhibitors can contribute 5–10% of water-soluble proteins.
2) Control of endogenous enzymes: Some authors believe inhibitors control activity of proteolytic enzymes.
3) Protection or dissuasion: Proteinase inhibitors might inhibit proteolytic digestive enzymes of invading insects or secretive proteinases of microorganisms (Bewley and Black, 1985).

Several inhibitors were identified in buckwheat seeds by various authors. They can be separated into two main groups 'anionic and cationic inhibitors' based on their behaviour in ion-exchange chromatography. In addition, they can be categorized by molecular weight values (Kiyohara and Iwasaki, 1985).

Functional properties of buckwheat

Buckwheat protein product (BWP) has various potential functional properties. BWP is composed of 65.8% w/w protein, 22.0% w/w lipids, 5.9% w/w non-fiber carbohydrates, and 3.1% w/w water. Defatted BWP is not suitable for utilization as a functional ingredient because food intake in rats fed with defatted BWP was significantly lower than in rats fed BWP (Tomotake et al., 2002). BWP has been claimed to exhibit several functional properties such as hypocholesterolemic activity in rats fed with a high cholesterol diet, suppression of body fat in rats (Kim et al., 2002), and suppression of induced colon carcinogenesis in rats (Liu et al., 2001). BWP is soluble over a wide pH range and might therefore be used in functional beverages (Tomotake et al., 2002).

Table 4. Percentage composition buckwheat grain and buckwheat products.

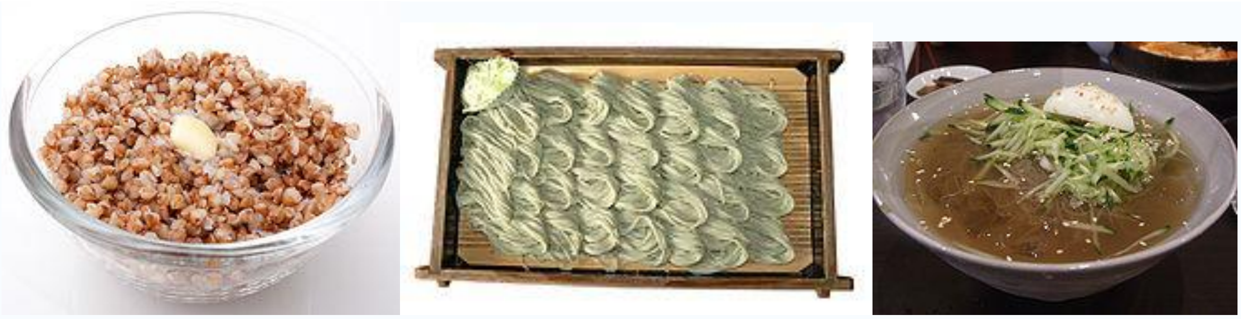
Grain or by product	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	N-free extract (%)	Ash (%)
Whole grain	10.0	11.2	2.4	10.7	64.0	1.7
Flour, light	12.1	7.8	1.5	0.7	76.7	1.2
Flour, dark	11.7	15.0	2.8	1.1	67.7	1.7
Groats	10.6	11.2	2.4	0.6	73.7	1.5
Hulls	8.0	4.5	0.9	47.6	36.8	2.2
Middlings	10.7	27.2	7.0	11.4	39.1	4.6
Farina	12.0	2.7	0.4	0.4	83.0	0.5

Utilization of buckwheat

Buckwheat has nutritional characteristics which place this crop in an excellent position for expanding utilization. Increasing the utilization of buckwheat as a food ingredient will require targeted market research. Since the cost of introducing new food products into the market is substantial, buckwheat processors has focused on the health benefits of buckwheat, then target those products in which buckwheat would be complementary. Present market expansion research indicates that buckwheat is well positioned to be included in specialty breads, pasta, snack foods, and ready to eat cereals (Gabrovska et al., 2002).

Buckwheat recipes and its cultural and aesthetic value

Buckwheat has gained both its cultural and the aesthetic value. The buckwheat plant is celebrated in Kingwood, West Virginia at their Buckwheat Festival where people can participate in swine, cow, and sheep judging contests, vegetable contests, and craft fairs. There are many rides and homemade, home grown buckwheat cakes and sausage. On Hindu fasting days (Navaratri mainly, also Maha Shivaratri and Janmastami), people eat items made of buckwheat flour. The preparation varies in Asia countries like India and Nepal. The famous ones are 'Kuttu Ki Puri' and 'Kuttu Pakoras'. In most of northern and western states they call this "Kuttu ka atta". In Punjab it is called as "Okhla" too and is extensively used in flour form (http://www.indobase.com/recipes/). Buckwheat groats are commonly used in western Asia and Eastern Europe. Buckwheat porridge, Soba noodles, Naengmyeon, Breton galette, buckwheat honey, buckwheat pancake etc. are the common recipies which are being used nowadays more popularly throughout the world.



Buckwheat porridge — Soba noodles — *Naengmyeon,* Korean cold noodle

Fig. 6: Different types of buckwheat recipes.

Buckwheat allergy

Proteinaceous compounds with MW 9,000, 16,000, 24,000, and 29,000 and trypsin inhibitor are proven to be potential major allergen (Yano et al., 1989). Buckwheat allergy can sometimes cause severe reactions which is an IgE-mediated immediate type reaction. Most known cases are in young children in Japan. In a screening of 92,680 children, 0.22% had a buckwheat allergy. Buckwheat-allergic patients are often associated with complain about urticaria (nettle rash), dyspnea (difficulty with breathing), facial angioedema, wheezing, asthma, anaphylactic shock and gastrointestinal symptoms such as vomiting and abdominal pain (Wieslander, 1996; Park et al., 2000).

In addition, people who are daily in contact with buckwheat or buckwheat products are likely to become allergic to buckwheat. It has been reported that health shop workers, bakers using buckwheat flour, and buckwheat noodle makers showed allergic symptoms when handling buckwheat. Besides asthmatic symptoms, buckwheat is the cause of various skin disorders (Wieslander et al., 1996). Because buckwheat is a food often consumed by coeliac patients, the incidence of buckwheat allergy among coeliac sufferers has been established. Patients with coeliac disease combined with other food allergies have an increased buckwheat intolerance of 30%. Normal coeliac sufferers show a buckwheat allergy of 1% (Wieslander, 1996).

Medicinal importance

- Buckwheat contains protein of high nutritional value, dietary fiber, resistant starch, rutin, D-chiro-inositol, vitamins and minerals which are associated with the suppression of colon carcinogenesis by reducing cell proliferation and with the suppression of mammary carcinogenesis by lowering serum estradiol (Liu et al., 2001; Prakash and Deshwal, 2013).
- Buckwheat proteins extract may be used as a potential functional food additive to treat hypertension, obesity, alcoholism, coliac disease as well as constipation (Kato et al., 2001).
- D-chiro-inositol is a part of the secondary messenger pathway for insulin signal transduction found to be deficient in Type II diabetes and Polycystic ovary syndrome (PCOS) (Horbowicz et al., 1998; Prakash et al., 2015).
- Starch, fiber, a high level of polyunsaturated essential fatty acids such as linoleic acids, vitamins (B1, C, and E), minerals, well balanced aminoacid and low content of prolamins has prophylactic role in gastrointestinal tract diseases (Kreft et al., 1996).
- Buckwheat proteins can exert a strong cholesterol-lowering effect and have a high biological value (Huff and Carroll, 1980).
- The lower Lys/Arg and Met/Arg ratios in buckwheat proteins are capable of lowering blood cholesterol level (Yoshimoto et al., 2004).
- Protein products of buckwheat to diets significantly lower the levels of cholesterol in serum, liver and gallbladder of hamsters and suppress the formation of gallstones by altering cholesterol metabolism (Tomotake et al., 2000). Protein extracts of buckwheat are more efficient

in lowering the blood cholesterol level, particularly that of LDL and VLDL.

- The diet rich in fiber from buckwheat offers significant protection against breast cancer for pre-menopausal women (Tomotake et al., 2000; Prakash et al., 2015).
- The hypocholesterolemic effect in humans is linked with a lower digestibility due to tannins, phytic acid and protease inhibitors of buckwheat proteins and the presence of fibre-like substances (Prakash and Deshwal, 2013; Tomotake et al., 2006; Prakash et al., 2015).
- Foods with higher levels of resistant starch usually have low glycemic index (GI) and low GI foods are important in improving diabetic control and can be used according to their blood glucose raising potential (Lerer et al., 1996).
- Plant sterols (so-called phytosterols) in buckwheat grains at low levels exert a positive effect on the blood cholesterol level (Krkoškova, 2005).
- The mineral boron found in buckwheat helps to harden the bones and have protective effect against oesteoporosis (Radovic et al., 1996).
- Buckwheat protein has been found to bind cholesterol tightly for reducing plasma cholesterol in people with hyperlipidemia (Wojciki, 1995).
- Glucoside named rutin and quercetin, the antioxidants in buckwheat have been mentioned in the treatment of chronic venous insufficiency, a medicinal chemical that strengthens capillary walls, reducing hemorrhaging in people with high blood pressure and increasing microcirculation in people with chronic venous insufficiency (Prakash and Deshwal, 2013; Abascal and Yarnell, 2007).

Other uses

- Buckwheat is used most frequently for soil covering as a green manure crop or smoother crop on gardens or small fields.
- As a green manure crop, buckwheat produces only modest biomass but offers rapid growth, improves soil tilt and makes phosphorous more available which produces a dark-colored honey with a distinctive flavor.
- An acre of buckwheat can support a hive of bees producing up to 150 pounds of honey, if prevailing weather conditions are suitable for good nectar production (reportedly, sunny days and cool nights are best).
- Buckwheat has long been used as a livestock and poultry feed.. The main value of the grain is that it is high in lysine, an essential amino acid that most grains are deficient in.
- Several research reports indicate that buckwheat is best used in a mixed feed ration, often as no more than one-third of the total mix (Ikeda, 2002).

Conclusion

There has been an increasing interest in the investigation of different extract obtained from plants for nutritional and therapeutic purposes. Buckwheat *(Fagopyrum esculentum)* is a rich source of protein, minerals, lipids, β-glucan, avenanthramides, indole alkaloid, flavonoids, triterpenoid, saponins, lipids and sterols. It exerts many pharmacological effects including antioxidant, anti-inflammatory, dermatological, immunomodulatory, antidiabetic, gastrointestinal, hypolipidemic, neurological, cardiovascular and many other biological activities. The treatment with buckwheat increased insulin activity and improved sensitivity for normalizing blood glucose level and reduce glucose production by the liver (Li et al., 1997; Ehrenshaft and Brambl, 1990). The glycaemic and insulinaemic response to buckwheat were tested in a small-scale clinical study (Czerwinski et al., 2004). This review study suggests that due to high biological importance of buckwheat, this pharmaceutical plant can be proved as medical boon by discovery new drugs reducing the several types of diseases growing fastly.

The amylases present in the seed of buckwheat play a very important role in the germination of seed which help in utilization of starch present in the endosperm of buckwheat seed (Bewley, 1997). Enzymes, being the most important products obtained for human needs have stimulated renewed interest in the exploration of industrially relevant enzymes from several natural sources including plants, animals and microorganism. Amylases are important enzymes employed in the starch processing industries for the hydrolysis of starch into simple sugars by the breakdown of α-(1, 4)- glucosidic linkages between adjacent glucose units there by hydrolyzing single glucose units from the non-reducing ends of amylase and amylopectin in a stepwise manner. This enzyme is extensively used in starch liquefaction, paper industries, food, pharmaceutical and sugar industries (Bradford et al., 2000; Botha et al., 1992).

Germinated buckwheat is an important raw material for food and functional food production, had better nutritional value than ungerminated buckwheat. As a result, the germinated seeds or sprouts are nutritionally superior to their original seeds with higher levels of nutrients, lower amounts of compounds that interfere with the absorption of nutrients and increased protein and starch digestibility. It is important to promote ancient nutritive food crop, buckwheat for various health reasons (Zhang et al., 2015). The review also highlights that the germinated seeds and hydrolysis of starch could help in the prevention and treatment of various human diseases and is also helpful in improving the development of active components for functional food products and pharmaceuticals.

Conflict of interest statement

Authors declare that they have no conflict of interest.

References

Abascal, K., Yarnell, E., 2007. Botanicals for chronic venous insufficiency. J. Altern. Complement. Ther. 213, 304-311.

Asian Scientist, 2015. A Study by Researchers at Wilmar (Shanghai) Biotechnology Research and Development Center Co. Ltd., Wiley Online Library.

Belozersky, M. A., Dunaevsky, Y. E., 1999. Proteolytic enzymes and their inhibitors in buckwheat seeds. Russ. J. Plant Physiol. 46, 330-339.

Bewley, J. D., Black, M., 1985. Seeds: Physiology of Development and Germination. Plenum Press, New York.

Bewley, J.D., 1997. Seed germination and dormancy. Plant Cell. 9, 1055-1066.

Biacs, P., Aubrecht, E., Léder, I., Lajos, J., 2002. Buckwheat. In: Pseudocereals and Less Common Cereals (eds.: Belton, P., Taylor, J.). Springer Verlag, Berlin. pp.123-151.

Bonafaccia, G., Gambelli, L., Fabjan, N., Kreft, I., 2003. Trace elements in flour and bran from common and tartary buckwheat. Food Chem. 83, 1-5.

Botha, F.C., Potgeiter, G.P., Botha, A., 1992. Respiratory metabolism and gene expression during seed germination. J. Plant Growth Regul. 11, 211-224.

Bradford, K.J., Chen, F., Cooley, M.B., et al., 2000. Gene expression prior to radicle emergence in imbibed tomato seeds. In: Advances and Applications in Seed Biology (Eds.: Black, M., Bradford, K. J., Vasquez-Ramos, J.). Proc. 6th Int. Workshop on Seeds. pp.231–251.

Campbell, C. G., 1997. Buckwheat, *Fagopyrum esculentum* Moench. IPGRI, Rome.

Chapkin, R. S., 2000. Reappraisal of the essential fatty acids. In: Fatty Acids in Foods and Their Health Implications. 2nd Edn. (Ed.: Chow, C. K.). Marcel Dekker, New York. pp.557-568.

Czerwinski, J., Bartnikowska, E., Leontowicz, H., et. al., 2004. Oat (*Avena sativa* L.) and amaranth (*Amaranthus hypochondriacus*) meals positively affect plasma lipid profile in rats fed cholesterol containing diets. J. Nutr. Biochem. 15, 622-629.

Dietrych-Szostak, D., 2006. Changes in the flavonoid content of buckwheat groats under traditional and microwave cooking. J. Agric. Food Chem. 23, 94-96.

Dietrych-Szostak, D., Oleszek, W., 1999. Effect of processing on the flavonoid content in buckwheat (*Fagopyrum esculentum* Möench) grain. J. Agric. Food Chem. 47 (10), 4384-4387.

Dorrel, D. G., 1971. Fatty acid composition of buckwheat seed. J. Am. Oil Chem. Soc. 48, 693-696.

Dua, I.S., Devi, U., Garg, N., 1991. Differential distribution of different saccharides and proteins in two types of grains growing in the same year of buckwheat (*Fagopyrum esculentum* Moench). Fagopyrum.11, 19-26.

Duffus, C.M., Binnie, J., 1990. Sucrose relationships during endosperm and embryo development in wheat. Plant Physiol. Biochem. 28, 161-165

Dziedzic, K., Górecka, D., Kucharska, M., Przybylska. B., 2012. Influence of technological process during buckwheat groats production on dietary fibre content and sorption of bile acids. Food Res. Int. 47(2), 279-283.

Ehrenshaft, M., and Brambl, R., 1990. Respiration and mitochondrial biogenesis in germinating embryos of maize. Plant Physiol. 93, 295-304.

Elpidina, E. N., Dunaevsky, Y. E., Belozersky, M. A., 1990. Protein bodies from buckwheat seed cotyledons: Isolation and characteristics. J. Exp. Bot. 41, 969-977.

Englyst, H. N., Kingman, S. M., Cummings, J. H., 1992. Classification and measurement of nutritionally important starch fractions. Eur. J. Clin. Nutr. 46, S33-S50.

FAO, 1990. Protein quality evaluation—Report of a joint FAO/WHO expert consultation. Food and Agriculture Organization of United Nations, Rome

Fonteles, M.C., Almeida, M.Q., Larner, J., 2000. Antihyperglycemic effects of 3-methyl-D- chiro-inositol and Dchiro- inositol associated with manganese in streptozotocin diabetic rats. Hormone and Metabolic Res. 32, 129–132.

Gabrovska, D., Fiedlerová, V., Holasová, M., Mašková, E., Smrčinov, H., Rysová, J., Winterová, R., Michalová, A., and Hutař, M. 2002. The nutritional evaluation of underutilized cereals and buckwheat. Food Nutr. Bull. Suppl. 23, 246-249.

Higasa, S., Fujihara, S., Hayashi. A., Kimoto K., Aoyagi, Y.,2011. Distribution of a novel angiotensin I-converting enzyme inhibitory substance (2"-hydroxynicotianamine) in the flour, plant parts, and processed products of buckwheat. Food Chem. 125, 607-613.

Horbowicz, M., and Obendorf R.L., 1992. Changes in sterols and fatty acids of buckwheat endosperm and embryo during seed development. J. Agr. Food Chem. 40, 745-750.

Horbowicz, M., Brenac, P., Obendorf, R.L., 1998. Fagopyritol B1, 0- α-d-galactopyranosyl-(1→2)-d-chiro-inositol, a galactosyl cyclitol in maturing buckwheat seeds associated with desiccation tolerance. Planta. 205, 1-11.

Huff, M.W., Carroll, K.K., 1980. Effects of dietary protein on turnover, oxidation, and absorption of cholesterol, and on steroid excretion in rabbits. J. Lipid Res. 21, 546-548.

Ikeda, K., 2002. Buckwheat: Composition, chemistry, and processing. Adv. Food Nutr. Res. 44, 395-434.

Ikeda, K., Shida, K., Kishida, M., 1994. Alpha-amylase inhibitor in buckwheat seed. Fagopyrum. 14, 3-6.

Inglett, G.E., Rose, D.J., Chen, D., Stevenson, D.J., Biswas, A., 2010. Phenolic content and antioxidant activity of extracts from whole buckwheat (*Fagopyrum esculentum* Möench) with or without microwave irradiation. Food Chem. 119(3), 1216-1219.

Jiang, P., Campbell, F.C.B., Pierce, G.J., Austria, A., Briggs, C.J., 2007. Rutin and flavonoid contents in three buckwheat species Fagopyrum esculentum, F. tataricum, and F. homotropicum and their protective effects against lipid peroxidation. Food Res. Int. 3, 356-367.

Joshi, B. D., Paroda, R.S., 1991. Buckwheat in India. NBPGR, Shimla Sci. Monograph No. 2. 117p.

Kalinova, J., Triska, J., Vrchotova, N., 2006. Distribution of vitamin E, squalene, epicatechin and rutin in common buckwheat plants (*Fagopyrum esculentum* Moench). J. Agric. Food Chem. 54, 5330-5335.

Kato, N., Kayashita, J., Tomotake, H., 2001. Nutritional and physiological functions of buckwheat protein. Recent Res. Dev. Nutr. 4, 113-119.

Kim, S. L., Kim, S. K., Park, C. H., 2002. Comparisons of lipid, fatty acids and tocopherols of different buckwheat species. Food Sci. Biotechnol. 11, 332-336.

Kiyohara, T., Iwasaki, T., 1985. Purification of trypsin inhibitors from buckwheat seeds. Agric. Biol. Chem. 49, 581-588.

Koyama, M., Nakamura, C., Nakamura, K., 2013. Changes in phenols contents from buckwheat sprouts during growth stage. J. Food Sci. Tech. 50(1), 86-93.

Kreft, I., Srabanja, V., Ikeda, S., Bonafaccia, G., 1996. Dietary value of buckwheat. Research Reports Biotechnical Faculty of the University of Lubljana. 67, 73-78.

Krkoškova, B., Mrazova, Z., 2005. Prophylactic components of buckwheat. Food Res. Int. 38, 561-568.

Lerer, M.M., Rizkalla, S.W., Luo, J., et al., 1996. Effects of longterm low-glycaemic index starchy food on plasma glucose and lipid concentrations and adipose tissue cellularity in normal and diabetic rats. Brit. J. Nutr. 75, 723-732.

Li, S., Zhang, Q. H., 2001. Advances in the development of functional foods from buckwheat. Crit. Rev. Food Sci. 41, 451-464.

Li, W., Lin, R., Corke, H., 1997. Physicochemical properties of common and tartary buckwheat starch. Cereal Chem. 74(1), 79-82.

Li, X.H., Park, N.I., Xu, H., Woo, S.H., Park, C.H., Park, S.U., 2010. Differential expression of flavonoid biosynthesis genes and accumulation of phenolic compounds in common buckwheat (*Fagopyrum esculentum*). J. Agric. Food Chem. 58, 12176-12181.

Lintschinger, J., Fuchs, N., Moser, H., Jäger, R., Hlbeina, T., Markolin, G., Gössler, W., 1997. Uptake of various trace elements during germination of wheat, buckwheat and quinoa. Plant Foods Hum. Nutr. 50, 223-237.

Liu, Z., Ishikawa, W., Huang, X., Tomotake, H., Watanabe, H., Kato, N., 2001. Buckwheat protein product suppresses 1,2- dimethylohydrazine-induced colon carcinogenesis in rats by reducing cell proliferation. J. Nutr. 131(6), 1850-1853.

Maccagnan, G., Pat, A., Collavo, F., Ragg, G. L., Bellini, M. P., 2004. Gluten-free beer containing rice malt and buckwheat. European Patent. EP 0949328B1.

Mazza, G., 1993. Storage, processing, and quality aspects of buckwheat seed. In: New Crops (Janick, J., Simon, J. E.). Wiley, New York. pp.251-254.

Mazza, G., Oomah, B. D., 2005. Buckwheat as a food and feed. In: Speciality Grains for Food and Feed (Abdel-Aal, E., Wood, P.). AACC International, St. Paul, MN. pp.375-393.

McGregor, W. G., McKillican, M.E., 1952. Rutin content of varieties of buckwheat. Sci. Agric. 32, 48-51.

Milisavljevic, M. D., Timotijevic, G. S., Radovic, S. R., Brkljacic, J. M., Konstantinovic, M. M., Maksimovic, V. R., 2004. Vicilin-like storage globulin from buckwheat (*Fagopyrum esculentum* Moench) seeds. J. Agric. Food Chem. 52, 5258-5262.

Ohnishi, O., Matsuoka, Y., 1996. Search for the wild ancestor of buckwheat II. Taxonomy of *Fagopyrum* (Polygonaceae) species based on morphology, isozymes and cpDNA variability. Genes Genet. Syst. 71, 383-390.

Pomeranz, Y., 1983. Buckwheat: Structure, composition, and utilization. CRC Crit. Rev. Food Sci. Nutr. 19, 213-258.

Pomeranz, Y., Marshall, H.G., Robbins, G.S., Gilbertson, J.T., 1975. Protein content and amino acid composition of maturing buckwheat. Cereal Chem. 52, 479-485.

Pomeranz, Y., Robbins, G.S., 1972. Amino acid composition of buckwheat. J. Agric. Food Chem. 20, 270-274.

Prakash, S., Deshwal, S., 2013. Alpha and Beta amylase activity of *Fagopyrum esculentum* (Buckwheat): A medicinal plant. Janaki Med. Coll. J. Med. Sci. 1(1), 53-58.

Prakash, S., Sharma, S., Yadav, K., Yadav, R., 2015. Biochemical analysis of amylases during germination of buckwheat (*Fagopyrum esculentum*) seeds: A pharmaceutical plant. Int. J. Sci. Res. Method. 2(1), 31-46.

Qian, J., Rayas-Duarte, P., Grant, L., 1998. Partial characterization of buckwheat (*Fagopyrum esculentum*) starch. Cereal Chem. 75; 365-373.

Radovic, S. R., Maksimovic, V. R., Varkonji-Gasic, E. I., 1996. Characterization of buckwheat seed storage proteins. J. Agric. Food Chem. 44(4), 972-974.

Rice-Evans, C. A., Miller, N. J., Paganga, G., 1997. Antioxidant properties of phenolic compounds. Trends Plant Sci. 2, 152.

Skrabanja, V., Elmstahl, H.G.M.L., Kreft. I., Bjorck, I.M.E., 2001. Nutritional properties of starch in buckwheat products: Studies *in vitro* and *in vivo*. J. Agric. Food Chem. 49(1), 490-496.

Skrabanja, V., Kreft, I., Golob, T., Modic, M., Ikeda, S., Ikeda, K., Kreft, S., Bonafaccia, G., Knapp, M., Kosmelj, K., 2004. Nutrient content in buckwheat milling fractions. Cereal Chem. 81, 172-176.

Steadman, K. J., Burgoon, M. S., Scuster, R. L., Lewis, B. A., Edwardson, S. E., Obendorf, R. L., 2000. Fagopyritols, D-*chiro*-inositol, and other soluble carbohydrates in buckwheat seed milling fractions. J. Agric. Food Chem. 48, 2843-2847.

Suzuki, T., T., Honda, Y., Mukasa, Y., 2004. Purification and characterization of lipase in buckwheat seed. J. Agric. Food Chem. 52, 7407-7411.

Taira, H., Akimoto, A., Miyahara, T., 1986. Effect of seeding time on lipid content and fatty acid composition of buckwheat grains. J. Agric. Food Chem. 34, 14-17.

Tomotake, H., Shimaoka, I., Kayashita, J., Yokoyama, F., Nakajoh, M., Kato, N., 2000. A buckwheat protein product suppresses gallstone formation and plasma cholesterol more strongly than soy protein isolate in hamsters. J. Nutr. 130, 1670-1674.

Tomotake, H., Yamamoto, N., Yanaka, N., Ohinata. H., Yamazaki,R., Kayashita, J., Kato, N., 2006. High protein flour suppresses hypercholesterolemia in rats and gallstone formation in mice by hypercholesterolemic diet and body fat in rats because of its low protein digestibility. Nutrition. 22, 166-173.

Ueda, T., Coseo, M. P., Harrell, T.J., 2005. Amultifunctional galactinol synthase catalyzes the synthesis of fagopyritol A1 and fagopyritol B1 in buckwheat seed. Plant Sci. 168, 681-690.

Watanabe, M., 1998. Catechins as antioxidants from buckwheat (*Fagopyrum esculentum* Moench) groats. J. Agric. Food Chem. 46, 839-845.

Wieslander, G., 1996. Review on buckwheat allergy. Allergy. 51, 661-665.

Wijngaard, H. H., Ulmer, H. M., Neumann, M., Arendt, E. K., 2005. The effect of steeping time on the final malt quality of buckwheat. J. Inst. Brew. 111(3), 275-281.

Wojciki, J., Barcew, W.B., Samochowiec, L., Rozewicka. L., 1995. Extractum fagopyri reduces athreosclerosis in high-fat diet fed rabbits. Die Pharmazie. 50, 560-562.

Yano, M., Nakmura, R., Hayakawa, S., Torii, S., 1989. Purification and properties of allergenic proteins in buckwheat seeds. Agric. Biol. Chem. 53, 2387-2392.

Yoshimoto, Y., Egashira, T., Hanashiro, L., Qhinata, H., Takase, Y., 2004. Molecular structure and some physiochemical properties of buckwheat starches. Cereal Chem. 81, 515-520.

Zhang, H.W., Zhang, Y.H., Lu, M.J., Tong, W.J., Cao, G.W., 2007. Comparison of hypertension, dyslipidaemia and hyperglycaemia between buckwheat seed-consuming and non-consuming Mongolian-Chinese populations in inner Mongolia, China. Clin. Exp. Pharmacol. Physiol. 34, 838-844.

Zhang, G., Xu, Z., Gao, Y., Huang, X., Zou, Y., Yang, T., 2015. Effects of germination on the nutritional properties, phenolic profiles and antioxidant activities of buckwheat. J. Food Sci. 80(5), H1111- H1119.

Zielinski, H., Ciska, E., Kozlowska, H., 2001. The cereal grains: Focus on vitamin E. Czech J. Food Sci. 19, 182-188.

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