Open Access Research Journal of
Chemistry and Pharmacy
Journals home page: https://oarjpublication/journals/oarjcp/
ISSN: 2783-0276 (Online)

(REVIEW ARTICLE)

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Human health benefits from buckwheat nutrients

Muhammad Arshad Ullah [1,*] and Ali Hassan [2]

[1] *Pakistan Agricultural Research Council, Islamabad, Pakistan.*
[2] *PMAS- University of Arid Agriculture, Rawalpindi, Pakistan.*

Open Access Research Journal of Chemistry and Pharmacy, 2021, 01(01), 047–059

Publication history: Received on 01 March 2021; revised on 10 April 2021; accepted on 13 April 2021

Article DOI: https://doi.org/10.53022/oarjcp.2021.1.1.0031

Abstract

Buckwheat contains a variety of nutrients in its grains. The main compounds are proteins, rutin, polysacchardes, dietary fibre, lipids, polyphenols and micronutrients (minerals and vitamins). The total content of these components depends on different factors, such as the species and the environment. The amino acid composition of buckwheat proteins is well balanced and of a high biological value, although the protein digestibility is relatively low. Buckwheat grains are an important source of microelements, such as: Zn, Cu, Mn, Se, and macro elements: K, Na, Ca, and Mg. With 80% unsaturated fatty acids more than 40% are constituted by polyunsaturated fatty acid (PUFA). The significant contents of rutin, catechins and other polyphenols as well as their potential antioxidant activity are also of significance to the dietary value. Moreover, buckwheat grains are a rich source of TDF (total dietary fibre), soluble dietary fibre (SDF), and are applied in the prevention of obesity and diabetes. An increasing incidence of allergy manifestations or symptoms is observed in people who consume buckwheat-containing food products often and in high quantities. The main reason for such immunological disorders is low molecular weight proteins, particularly those with molecular weights of 15, 22, or 26 kDa. These are concentrated in the peripheral parts of endosperm and embryo, hence the highest quantity of B vitamins is found in the bran. Tartary buckwheat bran contains about 6% of daily therapeutic doses of pyridoxine, effective in the reduction of blood plasma homocysteine levels. Protein extracts are more efficient in lowering the blood cholesterol level, particularly that of LDL and VLDL. Buckwheat proteins products (BWP) are acknowledged as preventive nutrients. They use advisable modifications, e.g. enzymatic modifications that consist in enzymatic separation of allergenic constituents or controlled fermentations performed by yeast or mould strains. 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. Buckwheat grains contain higher levels of vitamin B_1 (thiamine), B_2 (riboflavin), E (tocopherol) and B_3 (niacin and niacinamide) compared with most cereals. Generally, tartary buckwheat has more vitamin B_1, B_2 and B_3, but less vitamin E than common buckwheat. In general, tartary buck wheat has higher levels of vitamin B than common buck-wheat. Thiamine-binding proteins can improve the stability of thiamine during storage and improve the bioavailability of thiamine. Levels of vitamin C and the sum of vitamin B1and B6 can be increased by germinating buckwheat. The level of vitamin C can be increased by up to 0·25mg/g in buckwheat sprouts. Wheat, barley, oat, rye and buckwheat groats exhibit the same maximum level of tocopherols, with γ-tocopherol being the main one.

Keywords: Rutin; Polyunsaturated fatty acid; Niacin; Thiamine-binding proteins; Polypherols

1. Introduction

The main producers of buckwheat are China, Russian Federation, Ukraine, and Kazakhstan [1; 2]. It is also produced in Slovenia, Poland, Hungary, and Brazil. There are some botanical and physiological similarities between buckwheat and weeds, one of them being the ability to correct growth without the use of artificial fertilizers or pesticides. Moreover, buck-wheat absorbs less water and lower amounts of nutrients from soil than other main crops [1].

*Corresponding author: Muhammad Arshad Ullah
Pakistan Agricultural Research Council, Islamabad, Pakistan.

For many years, the cultivation of buckwheat was in decline, yet recently its has been observed to increase because of the health-promoting proper-ties of its grains. Buckwheat grains and other tissues contain numerous nutraceutical compounds [1] and they are rich in vitamins, especially those of B group [3]. The amino acid composition of buckwheat proteins is well balanced and of a high biological value [4], although the protein digestibility is relatively low [5]. Buckwheat grains are an important source of microelements, such as: Zn, Cu, Mn, Se [6], and macro elements: K, Na, Ca, Mg [7]. With 80% unsaturated fatty acids more than 40% are constituted by polyunsaturated fatty acid (PUFA) [8]. The significant contents of rutin, catechins and other polyphenols as well as their potential antioxidant activity are also of significance to the dietary value. Moreover, buckwheat grains are a rich source of TDF (total dietary fibre), soluble dietary fibre (SDF), and are applied in the prevention of obesity and diabetes [9].

Buckwheat grains contain a variety of nutrients, the main compounds being: proteins, polysaccharides, dietary fibre, lipids, rutin, polyphenols, micro- and macro elements [10]. The total content of components depends on the variety or environmental factors [11]. The high stability of buck-wheat species should be emphasized taking into consideration the content of protein in grains, in comparison with that determined currently in three Polish varieties of buckwheat [12].

Bran milling fractions of buckwheat have been shown to be characterized by a high concentration of proteins [13]. The major protein fractions of the grains are water-soluble and salt-soluble albumins and globulins representing almost one-half of all buckwheat proteins. Globulins consist of 12–13 subunits with molecular weights from 16 kDa to 66 k Da [13]. The main storage protein of buckwheat grains is 13S globulin [1]. Buckwheat prolamins have a different characteristic in comparison to wheat, barley, and rye prolamins, which enables buckwheat grains application in the prophylactic of gastrointestinal tract diseases, mainly celiac disease. Buckwheat grains may constitute a valuable source of dietary proteins with a high content of essential amino acids, which is important for people who do not tolerate gluten proteins [14] or with proteins deficiency in the diet. An increasing incidence of allergy manifestations or symptoms is observed in people who consume buckwheat-containing food products often and in high quantities. The main reason for such immunological disorders is low molecular weight proteins, particularly those with molecular weights of 15, 22, or 26 kDa [15; 16; 17].

Current results of starch analysis in buckwheat grains of three Polish varieties have shown that the starch content lies in a narrow range, i.e., from 63% to 66% d.m. [12]. Resistant starch in buck-wheat grains of three Polish varieties constituted from 16% to over 18% d.m., while the Kora variety stood out from the other varieties [12]. Starch is not only a significant source of energy for humans; it is also reported to interact with the gut micro flora [18; 19]. Soluble carbohydrates, including fagopyritols, are concentrated mainly in the embryo, their concentration is low in endosperm whereas their total contents ranges from 1% to 6% [20]. Fagopyritol A1 and Fagopyritol B1 are the most remarkable of all the fagopyritols accumulated. Fagopyritol A1 [21] is an active substance that may be used in the treatment of e.g., diabetes and polycystic ovarian syndrome (PCOS) [22].

According to the current definition, dietary fibre is the edible part of a plant or analogous carbohydrates that is resistant to digestion and absorption in the human small intestine but is partly or completely fermented by micro flora in the large intestine [23]. Dietary fibre consists also of oligosaccharides, polysaccharides, and other hydrophilic derivatives [24]. In general, IDF includes cellulose, lignins, and certain non-cellulosic polysaccharides, while SDF includes pectins and some associated non-cellulosic polysaccharides [9]. The whole grains contain 7% TDF, while bran with hull fragments has 40% TDF [25]. Buckwheat grains contain from 1.5% to 4% of total lipids [25]. The highest concentration of lipids was found in the embryo (7–14%), whereas the lowest in the hull (0.4-0.9%) [26].

Fatty acids may play a role in modifying the risk of breast, colon, and prostate cancer incidence. Polyunsaturated fatty acids (PUFA), such as n-3 and n-6, are often referred to as factors provoking the modulation of the immunological system in humans [27]. Generally, the content of minerals in buckwheat grains and their morphological fractions (dry base) reaches: 2–2.5% in whole grains, 1.8–2.0% in kernel, 2.2–3.5% in dehulled grains, about 0.9% in flour, and 3.4–4.2% in hulls [1]. Trace elements, e.g., chromium (Cr) or selenium (Se), are occasionally detected at very low levels. [6] reported after cultivation experiments reported that foliar fertilization makes buckwheat grains a rich source of dietary Se and a useful raw material for enriched food products [6 ;7;25] Buckwheat grains were also demonstrated to contain vitamins: B1, B2, B6 [3]. These are concentrated in the peripheral parts of endosperm and embryo, hence the highest quantity of B vitamins is found in the bran. Tartary buckwheat bran contains about 6% of daily therapeutic doses of pyridoxine [28], effective in the reduction of blood plasma homocysteine levels.

Generally, flavonoids content of F. tartaricum (about 40 mg/g) is higher than that of F. esculentum (10 mg/g) [1; 29]. [30] rank buckwheat (Fagopyrumsp.) among alleopathic plants. Antioxidant activity is the fundamental prophy-lactic property important for the human organism. A variety of biological functions, e.g. antimuta-genic, anticarcinogenic, antiaging, originate from that property [31].

Rutin, quercetin, orientin, vitexin, isovitexin, and isoorientin were identified in buckwheat hulls [32]. Some types of buckwheat flour could be considered as food with a high content of flavonoids, expressed as rutin, since their contents are higher than in cereal grains, cabbage, apple, red wine or tea [33]. The level of fagopyrins in buckwheat grains is very low and their isolation is difficult. It was reported that fagopyrins found in buckwheat can be utilized in the treatment of type II diabetes [1; 2; 34]. Prolamins of the gluten proteins complex found in wheat, barley, rye, and probably also oat react with the mucosa of small intestine, causing damage by activating the immune system to attack the delicate lining of the gut, which is responsible for absorbing nutrients and vitamins [35; 36].

Buckwheat proteins may show a strong supple-mental effect with other vegetable proteins due to the well-balanced amino acid composition [1]. Protein extracts are more efficient in lowering the blood cholesterol level, particularly that of LDL and VLDL [37]. Buckwheat proteins products (BWP) are acknowledged as preventive nutrients [5]. They use advisable modifications, e.g. enzymatic modifications that consist in enzymatic separation of allergenic constituents or controlled fermentations performed by yeast or mould strains [16]. They can suppress gallstone formation better than can soy protein isolates [20; 38]. Numerous experiments have proved that buckwheat proteins extract may be used as a potential functional food additive to treat hyper-tension, obesity, alcoholism, as well as constipation [39]. In buckwheat grains dietary fibre contains about 7% of the soluble fraction whereas resistant starch (comparable with it in terms of the physiological functions) constitutes about 28% of total starch in the whole grain [12]. [40] investigated the effect of buckwheat products ingestionon the microbial composition of the colon of rats, the detection having been carried out on Enterobacteria and Bifidobacteria.

Honey obtained from buckwheat f lowers in-creases the ant oxidative potential of human blood serum and in vitro studies indicated that it protects lipoproteins of blood serum against oxidative processes more effectively than saccharic analogues [41]. Buckwheat has a powerful ecological adaptability that allows the plant to grow in almost all kinds of extreme environments [1].

Historically, it was a very popular food during the 17th–19thcenturies, although it was later neglected during the 20th century in Western countries because of competition from wheat [42]. Many species of buckwheat are grown around the world; however, only nine have agricultural and nutritional value [8]. China, the Russian Federation, Ukraine and Kazakhstan are the leading producers of common buckwheat [1; 43] with production also in Slovenia, Poland, Hungary and Brazil. There is interest in buckwheat for the production of nutraceutical preparations with the potential for functional food development that may provide health benefits beyond basic nutrition (1; 43;44]. Buckwheat has been named by many people during the history of its development. According to some researchers, the ancient Yi people of the Yunnan province called buckwheater, common buck wheat etchi, and tartary buckwheat erka [1].

Buckwheat contains a variety of nutrients in its grains. The main compounds are proteins, rutin, polysacchardes, dietary fibre, lipids, polyphenols and micronutrients (minerals and vitamins) [10; 45]. The total content of these components depends on different factors, such as the species and the environment [11; 45]. Whole buckwheat groats (the hulled seeds) contain 550mg/g starch, 120mg/g protein, 70mg/g total dietary fibre (TDF), 40mg/g lipid, 20mg/g soluble carbohydrates and 180mg/g other components such as organic acids, phenolic compounds, tannins, phosphorylated sugars, nucleotides and nucleic acids [43;46]. Detailed composition of buckwheat flour in comparison with wheat flour. Buckwheat flour is mostly derived from the endosperm consisting of 700–750mg/g starch, 60–100mg/g proteins, 20–240mg/g TDF, 10–30mg/g lipids and 130mg/g other components, while bran with little central endosperm consists of 360mg/g proteins, 180mg/g starch, 150mg/g TDF, 110mg/g lipids, 60mg/g soluble carbohydrates and 70mg/g other components (43; 45;47; 48; 49]. Buckwheat bran is a rich source of dietary fibre, and in particular bran with hull fragments contains 400mg/g TDF, of which 250mg/g is soluble dietary fibre (SDF), while bran without hull fragments contains 160mg/g TDF, of which 750mg/g is soluble. Bran fractions also contain the highest concentration of protein among all milling fractions [13; 50]. It is important to note that buckwheat fibre is free of phytic acid, a major anti-nutritional factor in common wheat [51] . Buckwheat contains about the same amount of total lipids as wheat rye [52]. Buckwheat is nutritionally superior in fatty acid composition to cereal grains with 800mg/g unsaturated fatty acids, out of which 40mg/g of fatty acids are polyunsaturated [51]. In another study by [53] total saturated fatty acid was 200mg/g, while unsaturated fatty acid was 790mg/g, with a major fraction of 460mg/g linoleic acid.

In buckwheat seeds, the protein content ranges from 85·1 to 188·7mg/g depending on the variety [1; 8; 14]. The buckwheat proteins include albumin, globulin, prolamin and glutelin [54], but the relative content of these individual protein fractions show considerable variation and are dependent on variety. Buckwheat protein consists of 180mg/g albumin, 430mg/g globulin, 8mg/g prolamin, 230mg/g glutelin and 50mg/g other nitrogen residues [54]. It is generally recognized that albumin and globulin are the major storage proteins in buckwheat seeds, and prolamin and glutelin content are very low [55]. Buckwheat protein isolate (BPI) is composed mainly of globulin and albumin fractions. [56] studied the conformational properties of globulin and albumin fractions from common buckwheat seeds and com-pared them with those of BPI; they concluded that albumin from buckwheat seed had a higher content of uncharged polar amino acids, but lower acidic amino acids than globulin. Due to the well-balanced amino acid composition, buckwheat proteins have a high biological value, and the main disadvantage of buckwheat is its low protein digestibility (79·9%). Similarly, proteins of the albumin family with disulphide bonds appear to be responsible for the allergic response that is induced by buckwheat products [57].

The protein content in buckwheat is significantly higher than in rice, wheat, sorghum, millet and maize. Similarly, its protein content is the second highest after oat flour. Buckwheat has a well-balanced amino acid profile with a good quality of lysine which is generally recognized as the first limiting amino acid in wheat and barley and arginine. The quality of protein can be judged by the fact that buckwheat flour has an amino acid score of 100, which is one of the highest amino acid scores among plant sources [58]. No or low gluten types have been identified in buckwheat, thus contributing as an ingredient in the gluten-free diet for people suffering from celiac disease. 'Resistant proteins' such as those in buckwheat are also effective in lowering blood cholesterol [38]. These proteins lower the activity of angiotensin converting enzyme (ACE) and directly control hypertension (4; 38; 39). Rat feeding experiments showed that high-fat diets and overeating did not affect the body weight of the animals when buckwheat protein hydrolysate was included in the diet. This protective effect was much weaker for soybean protein hydrolysates [38]. [5] utilized buckwheat protein extract containing c. 730mg/g buckwheat protein to assess its effect on induced colon tumours in rats. It was shown that dietary buckwheat protein reduced the incidence of colonic adenocarcinomas by 47%. Buckwheat protein also reduced carcinoma cell proliferation and expression in colonic epithelium. The results clearly suggest that buckwheat proteins have a protective effect against colon carcinogenesis.

The nutritional functions of essential minerals in buckwheat and foods prepared from it have been studied by many scientists (60.61, 6263 and 64). All of these studies concluded that buckwheat seeds are a good source of many essential minerals. In comparison with other cereals such as rice, wheat flour or maize, buckwheat contains higher levels of zinc (Zn), copper (Cu) and manganese (Mn) [50].

The bioavailability of Zn, Cu and potassium (K) from buckwheat is especially high. It has been determined that 100 g of buckwheat flour can provide c.13–89% of the recommended dietary allowance (RDA) for Zn, Cu, magnesium (Mg) and Mn. A major quantity of these minerals exists in bran portions, followed by endosperm. Buckwheat flour contains relatively high levels of Zn, Cu, Mn and Mg, with a slightly lower content of calcium (Ca) in comparison with other flours, especially wheat [43]. Recently, [64] compared the composition of eight essential minerals, i.e., Fe, Zn, Cu, Mn, Ca, Mg, K and phosphorus (P), of buckwheat flour to those of cereal flours by using an in vitro enzymatic digestion technique. The results showed a higher content of essential minerals in buckwheat flour in comparison with other cereal flours. Further enzymatic digestion proved that a larger portion of the Zn, Cu and K were released in soluble form from the buckwheat flour, relative to that in cereal flours. 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. Buck wheat grains contain higher levels of vitamin B1(thiamine), B2 (riboflavin), E (tocopherol) and B3 (niacin and niacinamide) compared with most cereals. Generally, tartary buckwheat has more vitamin B1, B2 and B3, but less vitamin E than common buckwheat [43; 64]. In general, tartary buck wheat has higher levels of vitamin B than common buck-wheat [65]. Thiamine-binding proteins can improve the stability of thiamine during storage and improve the bioavailability of thiamine [1]. Levels of vitamin C and the sum of vitamin B1and B6 can be increased by germinating buckwheat. The level of vitamin C can be increased by up to 0·25mg/g in buckwheat sprouts. Wheat, barley, oat, rye and buckwheat groats exhibit the same maximum level of tocopherols, with γ-tocopherol being the main one [66; 67].

Differences in tocopherol forms have been attributed to different cultivars of common buckwheat [33; 67]. Tartary buckwheat contains higher levels of tocopherols than common buckwheat [67].

Iminosugars in buckwheat Polyhydroxylatedpiperidines (azasugars or imino-sugars) have gained increasing synthetic interest due to their high biological activity as glycosidase inhibitors [68]. If used as a dietary supplement or functional food component, D-fagomine may reduce the risks of developing insulin resistance, becoming overweight and suffering from an excess of potentially pathogenic bacteria [69]. These azasugars are potential therapeutic agents for the treatment of a wide range of diseases, including diabetes, cancer, AIDS, viral infections and many more [70].

[69] determined D-fagomine and its diastereomer, 3,4-di-epi-fagomine in buckwheat groats, bran and leaves, and also in buckwheat flour. The highest content of D-fagomine and 3·4-di-epi-fagomine was present in groats (44 and 43mg/kg, respectively). *Fagopyrum tataricum* seeds contained less D-fagomine than F. esculentum [69].

The amount of TDF in buckwheat varies with differences in genetic and environmental factors. The major components of TDF are cellulose, non-starch polysaccharides and lignin. These are concentrated in the cell walls of starchy endosperm, aleurone, seed coats and hulls [50]. Bran fractions obtained by the milling of buckwheat are especially rich in dietary fibre (130–160mg/g), but buckwheat flours contain considerably lower amounts of fibre (17–85mg/g) [25]. For nutritional purposes, TDF is classified into SDF and insoluble dietary fibre (IDF). Insoluble dietary fibre (IDF) decreases transit time in the stomach, small intestine and colon and increases faecal mass. It is commonly used as a bulking agent to prevent or treat constipation. Soluble dietary fibre, due to its high viscosity, slows gastric emptying, reduces the adsorption of certain nutrients and increases transit time in the small intestine by slowing down glucose absorption. Soluble dietary fibre and to a lesser extent IDF are fermented by microflora in the digestive system to produce SCFA, implicated in serum cholesterol and colon cancer reduction. A considerable portion of buckwheat dietary fibre is soluble [50]. More recently, arabinose and glucose residues have also been identified in water-extractable buckwheat polysaccharides. Buckwheat bran containing hulls hasc. 400mg/g fibre, including 250mg/g soluble fibre, while 'pure' bran without hulls contains c. 160mg/g fibre, in-cluding 750mg/g soluble fibre [71; 72]. Depending on the type of technological processes applied in the production of buckwheat groats, the level and fraction composition of dietary fibre affects the functional properties [73; 74]. In buckwheat grains, dietary fibre constitutes 50–110mg/g, and the soluble fibre content is 30–70mg/g, while the amount of the insoluble fibre is 20–40mg/g [8].

Functional properties of dietary fibre, such as water holding capacity and cation binding, play a significant role in the prevention of diet-dependent diseases, e.g. obesity, atherosclerosis and colon cancer [75; 76; 77]. [73] examined the influence of thetechnological process of buckwheat groat production on dietary fibre content and its fraction with the absorption of selected bile acids by buckwheat groats and products such as buckwheat grains, buckwheat grains after roasting, buckwheat hull, buckwheat bran, whole buckwheat groats, broken buckwheat groats and buckwheat waste. They recorded the highest content of TDF in hulls, while the lowest was in whole and broken buckwheat groats. Buckwheat hulls contain higher lignin and cellulose fractions, while the hemicellulose fraction predominated in broken groats. Similarly, roasting of buckwheat grains resulted in an increase in the content of dietary fibre and the all-fractions dietary fibre [73].

Buckwheat flour contains 700–910mg/g of starch depending on the flour types, and the starch consists of 250mg/g amylose and 750mg/g amylopectin [45; 78]. Scanning electron microscope (SEM) studies showed granules of buckwheat starch to be polygonal and of irregular shape [79]. The buckwheat starch has small granules as particles of grain cotyledons and they are smaller than those of maize starch (12·2μm), tapioca starch (18μm) and potato starch (30·5μm) [80]. It has been found that the consumption of boiled buckwheat groats or bread baked using 0·50 buck wheat flour induced significantly lowered post-prandial blood glucose and insulin responses com-pared with white wheat bread [81]. Buckwheat products may provide an important source of retrograded starch and RS [82]. The in vitro rate of starch hydrolysis and RS formation in boiled and baked buckwheat indicated the highest concentration of RS in boiled buckwheat groats (60mg/g total starch basis), while the RS level in bread products based on different proportions of buckwheat flour and groats varies from 90 to 40mg/g.

The rate of in vitro amylolysis was significantly lower ($P<0·05$) in all buckwheat products in comparison with white flour bread [81]. A variety of biological functions such as antimutagenic, anti-carcinogenic and antiaging originated from an anti-oxidant property [31]. The primary antioxidants in buck wheat are rutin, quercetin and hypering . Buckwheat bran and hulls have 2–7 times higher antioxidant activity than barley, triticale and oats [72]. [33] established the following hierarchy of antioxidant activity for 80% metha-nolic extracts which originated from different whole grains: buckwheat>barley>oat>wheat>rye.

The antioxidant activities of buckwheat are comparable to butylatedhydroxyanisole (BHA), butylatedhydroxytoluene (BHT) and tertiary butylhy-droquinone (TBHQ), as determined by 1, 1-diphenyl-2-picrylhydrazyl (DPPH) assay and the Rancimat method [84]. [3] extracted tartary buckwheat seeds (F. tataricumGaertn.) with methanol and found that tartary buck-wheat seeds contained more rutin (8–17mg/g dry weight (DW)) than commonbuckwheat seeds (0·1mg/g DW). For buckwheat, 80% methanol was found to extract 64 times more phenolic compounds and four times the antioxidant activity than water [33]. The presence of proanthocyanidins in flour (1·59mg/g DW) was confirmed by [84]. [85;86] studied the antioxidant activity in buckwheat with water, 0·50 aqueous ethanol, or total ethanol using microwave irradiation or a water bath for 15min at various temperatures (23–150 °C). They found the highest antioxidant activity of 5·61–5·73μmol Trolox equivalents/g in total ethanol extract at 100 and 150 °C, independent of the heat source. [49] proved antioxidant activity by reducing power and DPPH radical scavenging ability in buckwheat enhanced wheat bread. Similarly, [87] proved that buckwheat flours exhibited significantly higher ($P<0{\cdot}05$) anti-radical activity on hydroxyl (OH), superoxide anion (O_2.) and DPPH radicals, antioxidant activity and reducing power in comparison with wheat fractions.

Flavonoids are polyphenolic compounds that are ubiquitous in plants and are a group of more than 4000 polyphenolic compounds that occur naturally in foods of plant origin. They have been shown to possess a variety of biological activities at non-toxic concentrations in organisms. These compounds possess a common phenyl benzopyrone structure (C_6-C_3-C_6) and they are categorized according to the saturation level and opening of the central pyranring, mainly into flavones, flavanols, isoflavones, flavonols, flavanones and flavanonols [88]. Phenolic com-pounds in buckwheat also possess antioxidant activity [31; 89; 90]. Four flavonol glycosides including rutin, quercetin, kaemferol-3-rutinoside and a trace amount of a flavonoltriglycoside were found in the methanol extract of buckwheat [91]. Tartary buckwheat has been shown to contain a higher content of flavonoids (19·02mg/g) in comparison with common buckwheat (0·28mg/g)[92].

Buckwheat contains more rutin compared with other grain crops. This is a quercetin-3-rutinoside with antioxidant, anti-inflammatory and anticarcino-genic properties, and it can also reduce the fragility of blood vessels related to haemorrhagic disease and hypertension in humans. It has been found that whole buckwheat contains 2–5 times more phenolic com-pounds than oats or barley, while buckwheat bran and hulls have 2–7 times higher antioxidant activity than barley, triticale and oats [31; 72]. Buckwheat contains a majority of phenolic compounds present in the free form and distributed throughout the entire grain. Recently, 2-hydroxy-3-O-β-D-glucopyranosil-benzoicacid,1-O-caffeoyl-6-O-alpha-rhamnopyranosyl-β-glycopyranosideand epicatechin-3-(3′′-O-methyl) gallate were identified in buckwheat by reverse phase high performance liquid chromatography– electrospray ionisation-mass spectrometry [91], and then again with reverse phase high performance liquid chromatography–electrospray ionization-time of flight-mass spectrometry [93]. The flavonoid content and composition in seeds vary between different buckwheat species and devel-opment phases. Flavonoid content in F. tataricum is generally higher than that in F. esculentum. In F. tataricumseeds, the flavonoid content isc.40mg/g, while that of F. esculentumseedsisc. 10mg/g [1]. In F. tataricum flowers, leaves and mstems, the flavonoid content can exceed 100mg/g.

Buckwheat tissues can serve as very useful resources for high-quality flavonoids, though flavonoid con-tent varies with development and is significantly influenced by the contents of phenylalanine and tyrosine and the activity of kinetin in the issues along with different existing forms of nitrogen in the soil [1]. Six flavonoids have been isolated and identified in buckwheat grain. All six flavonoids (rutin, quercetin, orientin, vitexin, isovitexin and isoorientin) have been found in buckwheat hulls [91]. Epidemiological studies have suggested a protective role of dietary flavonoids against coronary heart diseases and possibly cancer [29]. In recent years, flavonoids have attracted increasing interest because they have various beneficial health effects such as anti-allergic, antiviral,anticancer and anti-oxidation properties [29]. The flavonoid content in tartary buckwheat (c. 40mg/g) is higher than that in common buckwheat (10mg/g) [1]. Flavonoids are known for their effectiveness in reducing cholesterol levels in the blood, keeping. Important phenolic compounds in buckwheat: A, isorientin; B, orientin; C, rutin; D, vitexin [93]. Nutritional profile of capillaries and arteries strong and flexible, reducing high blood pressure and reducing the risk of arterio-sclerosis [1; 3]. [93] quantified 32 free and 24 bound phenolic compounds in buckwheat flour and buck-wheat spaghetti, with two new compounds, i.e., protochatechuic-4-O-glucoside acid and procyanidinproving the further phenolic potential of buckwheat. [94] reported the effect of methyl jasmonate on phytochemical production in buck-wheat sprouts cultivated in dark conditions, and their findings proved that isoorientin, orientin, rutin and vitexin were the main flavonoids in buckwheat sprouts. Similarly, buckwheat flour (476·3 and 618·9mg GAE/g extract) contain polyphenolic con-tents four times higher than wheat flour (37·1 and 137·2mg GAE/g extract) [87].

Rutin (quercetin-3-beta-D-rutinoside) is an important therapeutic substance that favourably influences the increase of blood vessel elasticity, the treatment of circulatory disorders and athero-sclerosis, the reduction of blood pressure, and stimulates the utilization of vitamin C. Rutin is widely present in plants, but is relatively rare in their edible parts. It was first detected in Rutagraveolens, which gave the common name to this pharmaceutically important substance. No rutin has been found in cereals or pseudo cereals except buckwheat, which can be used as a good source of dietary rutin [92; 95]. The content of rutin is dependent on the buckwheat genotype, growing conditions, developmental phase, plant part and year of harvest. Most rutin is accumulated in the inflorescence (up to 0·12mg/g DW), in stalks (0·004–0·01mg/g DW), upper leaves (0·08–0·10mg/g DW) and 0·12–0·36mg/g DW in grains depending on the variety and growth conditions [95]. The highest quantity of rutin is found in leaves immediately before flowering, therefore providing the opportunity for utilizing buckwheat tops for the natural fortification of food with rutin. Among fruits, vegetables and grain crops, grapes and buckwheat are the most important rutin-containing foods. Ecological factors such as ultra-violet (UV) irradiation may also have a great influence on rutin content [96].

In a research report by [97], rutin content in 50 seeds and plants of different tartary buckwheat strains from all over the world was compared. These 50 strains were collected from China (27 strains), India (5 strains), Nepal (9 strains), Bhutan (3 strains), Pakistan (1 strain), Slovenia (3 strains) and Japan (2 strains). They found the rutin content in seed and plant parts of tartary buckwheat to be higher than that of F. esculentumandF. Cymosum (Park et al.2004). Similar results were obtained by [92; 98]. The rutin content of tartary buckwheat wasc. 3·2 times higher in the flower, c. 3·1 times in the stem and c.65 times higher in the seed compared with F. esculentum [98]. Similarly, rutin content in buck-wheat varied with cultivation region. Rutin content in the leaf, stem and seed of the strains collected from the Bhutan area were higher than in the strains collected from Slovenia and Pakistan [97].

Rutin has desirable physiological and biological properties, such as anti-oxidation, anti-inflammation, anti-hypertension, vasoconstrictive, spasmolitic and a positive inotropic effect [99]. Rutin also provides protection against gastric lesions, improves sight and hearing, protects against UV light, lowers plasma cholesterol, protects fromoxidative stress [100], and causes muscle hypertrophy and also sup-presses gallstone formation and cholesterol levels [99]. [101] concluded that adding rutin to the digestion mixture in the flour caused a significant increase in pepsin digestibility. Fagopyrin is a photo-sensitive substance found in buckwheat plants, belonging to the naphthodian-thrones and structurally related to hypericin. The fagopyrins found in buckwheat grains are unique, but the concentration is very low and isolation is difficult. In buckwheat, some anthranoides have also been found in concentrations which could cause very small laxative effects [102]. The fagopyrins found in buckwheat can be utilized in the treatment of type II diabetes [8].

Buckwheat seeds accumulate the soluble carbo-hydrates sucrose and fagopyritols in the embryo and aleurone tissues. Fagopyritols are carbohydrate com-pounds which were first identified in buckwheat and are ex-galactosyl derivatives (mono, di and trigalacto-syl derivatives) of D-chiro-inositol. Six fagopyritols representing two distinct series differing in bonding positions have been found in buckwheat seeds [20; 21; 103]. These are fagopyritol A1 (α-D-galactopyranosyl-(1?3)-1D-chiro-inositol), fagopyritol A2 (α-D-galactopyranosyl-(1?6)-α-D-ga-lactopyranosyl-(1?3)-1D-chiro-inositol), fagopyritol A3(α-D-galactopyranosyl-(1?6)-α-D-galactopyranosyl-(1?6)-α-D-galactopyranosyl-(1?3)-1D–chiro-inositol), fagopyritol B1(α-D-galactopyranosyl-(1?2)-1D-chiro-inositol), fagopyritol B2(α-D-galactopyranosyl-(1?6)-α-D-galactopyranosyl-(1?2)-1D-chiro-inositol) and fagopyritol B3 (α-D-galactopyranosyl-(1?6)-α-D-ga-lactopyranosyl-(1?6)-α-D-galactopyranosyl(1?2)-1D-chiro-inositol) [104]. Fagopyritol B1 and A1 [21; 103] are the major fagopyritols accumulated in buckwheat seeds, and these constitute 0·50 of the total soluble carbohydrates of buckwheat embryos [105]. Fagopyritols accumulate in the dicotyledonous embryo of buckwheat seeds,mostly in the cotyledons. Recently, [106] determined themolecular structure of fagopyritol A1 asO-α-D-galactopyranosyl-(1-3)-D-chiro-inositol by1H and13C NMR and concluded that fagopyritol A1 is a positional isomer of fagopyritol B1 (O-α-D-galactopyranosyl-(1-2)-D-chiro-inositol, which has a positive effect on blood glucose levels and insulin activity [107].

Buckwheat is the richest source of these carbo-hydrates. The bran milling fractions may contain26mg of fagopyritols per g DW, whereas dark and light buckwheat flours contain 7 and 3mg/g DW, respectively [107]. Buckwheat is being studied for use in treating type II diabetes [108] and can also help to control the development of polycystic ovaries: it contains D-chiro-inositol, a component of the secondary messenger pathway for insulin signal transduction found to be deficient in type II diabetes and polycystic ovary syndrome (PCOS). Research on D-chiro-inositol and PCOS has shown promising.

A buckwheat protein has been found to bind cholesterol tightly, thus reducing plasma cholesterol in people with hyperlipidemia. D-chiro-inositol is a component of galactosamineD-chiro-inositol, a putative insulin mediator (believed to be deficient in subjects with NIDDM because of an abnormalD-chiro-inositol metabolism. Adding D-chiro-inositol as a dietary supplement appeared to be effective in reducing the symptoms of NIDDM and PCOS [107]. Several research groups are developing sources for natural and synthetic supplies of D-chiro-inositol. One natural source of D-chiro-inositol (in free form and as galactosides, predominantly fagopyritol A1 and fagopyritol B1) is in buckwheat seed. During dry milling, fragments of the outer cotyledon adhere to the bran. Therefore, the bran milling fraction from buckwheat seed [20] can be used for the isolation and preparation of fagopyr-itols and can free D-chiro-inositol for the production of nutraceuticals and pharmaceuticals [20; 21; 105108]. Several buckwheat allergens have been identified, of which the 24 kDa (Fag e 1), 26 kDa and 67–70 kDa proteins have been suggested to be of importance [109]. Fag e 1, which is homologous to 11S or 12S globulin, has reacted with the serum IgE of all buckwheat allergy patients. The 16 kDa protein (Fag e 2), which is resistant to digestion, has been identified as a major buckwheat allergen in Japanese and Korean patients with buckwheat allergy [102].

2. Conclusion

This article reviews due to the importance of buck wheat as a nutritional grain crop for the improvement of human health to introduce the treatment of human diseases with nutrition. The main compounds are proteins, rutin, polysacchardes, dietary fibre, lipids, polyphenols and micronutrients (minerals and vitamins). The amino acid composition of buckwheat proteins is well balanced and of a high biological value, although the protein digestibility is relatively low. The significant contents of rutin, catechins and other polyphenols as well as their potential antioxidant activity are also of significance to the dietary value. Tartary buckwheat bran contains about 6% of daily therapeutic doses of pyridoxine, effective in the reduction of blood plasma homocysteine levels. Buckwheat grains contain higher levels of vitamin B_1 (thiamine), B_2 (riboflavin), E (tocopherol) and B_3 (niacin and niacinamide) compared with most cereals. Generally, tartary buckwheat has more vitamin B_1, B_2 and B_3, but less vitamin E than common buckwheat. The level of vitamin C can be increased by up to 0·25mg/g in buckwheat sprouts. Wheat, barley, oat, rye and buckwheat groats exhibit the same maximum level of tocopherols, with γ-tocopherol being the main one.

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