

Nutrient Content in Buckwheat Milling Fractions

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ABSTRACT

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Buckwheat seeds (*Fagopyrum esculentum* Moench) were milled into 23 fractions: seven fine flours, three coarse flours, four small semolina, two big semolina, six bran, and one husk fraction. A considerable variation in gross chemical composition was found among the milling fractions. The protein content varied from 4.4 to 11.9% (db) in flours and from 19.2 to 31.3% in bran fractions; starch varied from 91.7 to 70.4% in flours and from 42.6 to 20.3 in bran. The percentage of soluble dietary fiber contained

in total dietary fiber was higher in flours than in semolina and bran fractions. Ash, Fe, P, tannin, phytate content, and color were also investigated. A unique distribution of phytate was found in starch. Correlation is significantly positive in husk, bran, and semolina fractions, while correlation is significantly negative in flour fractions. Depending on technological or nutritional demands, appropriate fractions may be chosen to achieve the desired end-use product.

Buckwheat (*Fagopyrum esculentum* Moench) is one of the traditional crops cultivated in central and eastern Europe and in Asia, and it is now a part of the renewed interest in alternative crops for organic cultivation and for healthy foods. Traditionally, milled buckwheat can be used for pasta, blended bread, and other types of flour products.

One key issue is the design and development of functional foods with the aim of improving health and well being and reducing the risk of certain diseases (Anonymous 1999). Many positive physiological effects are associated with buckwheat. As it has no gluten, buckwheat is safe for patients with celiac disease (Skerritt 1986). Suitable textural properties for pasta and other products can be achieved by balancing buckwheat proteins and starch (Ikeda et al 1997). Buckwheat is also known as an abundant source of dietary minerals like zinc, copper, and manganese (Ikeda and Yamashita 1994).

One positive characteristic of buckwheat concerns the prevention and treatment of both hypertension and hypercholesterolemia. The preventive effect may be connected with the content of dietary fiber in buckwheat (He et al 1995). It has become increasingly apparent that dietary fiber components in foods may have a positive physiological effect in the gastrointestinal tract and also significantly influence the metabolism of other nutrients (Anonymous 1998). Similar effects are associated with the inclusion of resistant starch in the diet. According to our previous results, buckwheat groats contain an important amount of resistant starch (Skrabanja and Kreft 1998; Skrabanja et al 1998) and could thus be useful in preventing colon cancer. Moreover, flattened metabolic responses, as described by glycemic and insulinemic indices after the ingestion of buckwheat meals, have recently been confirmed (Skrabanja et al 2001; Kreft and Skrabanja 2002).

In different parts of the buckwheat plant and groats, Hagels et al (1995), Watanabe (1998), Kreft et al (1999), and Park et al (2000) found appreciable amounts of rutin, a metabolite that antagonizes the increase of capillary fragility associated with hemorrhagic disease or hypertension in man (Griffith et al 1944; Schilcher et al 1990).

Thus, many aspects suggest the use of buckwheat as a functional food. The purpose of this study was to evaluate the dietetic

potential of different possible buckwheat milling products, according to the content of nutrients and the relationship between different nutrient parameters such as starch, proteins, fat, ash, dietary fiber, iron, tannin, and phytic acid in 22 buckwheat milling fractions and in husks. Color of milling fractions was also investigated.

MATERIALS AND METHODS

Plant Materials

Buckwheat seeds (*Fagopyrum esculentum* Moench 'Siva'), grown in Slovenia in 1996, were subjected to successive milling to obtain as many different milling fractions as possible. In total, 23 buckwheat fractions including the husks were obtained by repeats of milling and sieving of individual sieving fractions, consecutively, in two types of roller mills (F. Bergant mill, Psata, Ljubljana) constructed in 1930. Details of milling procedures are reported by Modic (1998).

Fractions were divided on basis of combination of sieving and repeated milling into seven fine flours (FF 1–7) and three coarse flours (CF 1–3), four small semolina fractions (SS 1–4), two big semolina fractions (BS 1–2), six bran fractions (Br 1–6), and one as pure husks only (H). Yield of milling fractions is presented in Table I. Material was analyzed as raw and uncooked.

Analytical Methods

The procedure of the determination of total starch in general followed the method described by Tovar et al (1990), however, before the alkali treatment, the samples (two replicates of each) were soaked in a phosphate buffer (0.1M; pH 6.0). Total starch was determined enzymatically following solubilization in alkali (4M KOH), incubation with a thermostable α -amylase (Termamyl 300L DX; Novo Nordisk A/S, Copenhagen), and amyloglucosidase (EC 3.2.1.3, 3500 U/25 mL; Bushranger Mannheim, No. 1202 367). The content of glucose was assayed with the glucose oxidase-peroxidase reagent, and the starch content calculated using the conversion factor 0.9.

Total protein content in buckwheat flour fractions was analyzed with Kjeltac Auto System (Tecator AB, Sweden) by the Kjeldahl method (AOAC 1990). The nitrogen-to-protein conversion factor used was 5.7. Analyses were performed in triplicate. For crude fat determination, flour fractions were extracted with diethyl ether after acid hydrolysis in triplicate and determined gravimetrically (Matissek et al 1992). For ash determination, three replicates of each sample were ashed at 550°C according to Method 923.03 (AOAC 1990). Iron was determined colorimetrically by the use of 2,2'-bipyridyl (James 1995). Phosphorus was determined by the colorimetric method of Fiske and Subbarow (1925). Before analysis, the buckwheat milling fractions were ashed. Two replicates of each sample were analyzed.

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In the flour material, the insoluble and soluble dietary fibers were assayed following the modified enzymic gravimetric method of Prosky et al (1985, 1988). Two replicates for soluble and two for insoluble dietary fiber were also corrected for ash and protein.

Tannin contents were evaluated using the Vanillin-HCl test. Samples (in triplicate) were extracted in methanol for 20 min. Vanillin-HCl reagent (5 mL) or HCl (5 mL) in methanol as blank sample was added to the aliquots and then incubated for 20 min at room temperature. The absorbance of samples and blank were measured against distilled water at 500 nm, and the concentration of tannin was calculated from the standard curve using catechin in methanol as a standard solution (Earp et al 1981). The content of rutin was analyzed by capillary electrophoresis as described earlier (Kreft et al 1999).

Phytate was determined using the original colorimetric procedure based on Haug and Lantzch (1983) with some modifications. Duplicate samples of each fraction were extracted in 0.4M HCl for 1 hr. An extract aliquot and also a standard solution of phytate reference ($C_6H_6O_{24}P_6Na_{12} \times 9 H_2O$) were each combined with a ferric solution ($NH_4Fe(SO_4)_2 \times 12 H_2O$) and the mixtures were heated in a boiling water bath for 30 min. The samples and standards were then cooled to room temperature, when a mixture of 2,2-bipyridine and thioglycolic acid in distilled water was added. After 20 min, the absorbance at 519 nm was measured against distilled water.

The phytate in buckwheat flour was calculated from the calibration curve of standards.

Color Measurements and Granulometry

Color (L^* , a^* , and b^*) of buckwheat milling fractions was measured with a chromameter (CR-200b, Minolta, Tokyo, Japan). The L^* value indicates lightness, the a^* and b^* values indicate hue and chroma (a^* from green to red; b^* from blue to yellow) (CIE 1971). Granulometry analysis was performed using an automatic sieve (Buhler ML1-300) with circular oscillation; running time was 5 min; oscillation frequency was 200 turns/min with a run of 25 mm.

Statistical Analysis

The results were evaluated using the SPSS/PC+ program (v.11.0 for Windows, SPSS, Chicago IL). Correlation coefficients were calculated from the data of all fractions except the husks.

RESULTS AND DISCUSSION

Particle Size

Milling buckwheat seeds in a traditional roller mill resulted in different particle sizes that constituted the basis for differentiation between fine flour (FF), coarse flour (CF), small semolina (SS), big semolina (BS), bran (Br), and husks (H), respectively. In FF 1-7, the majority of particles were <129 μ m, while in CF 1-3, 77% of total weight passed a 183- μ m mesh sieve. The particle size range of SS 1-4 and Br 3-6 was 219-656 μ m; however, >50% of particles in BS 1-2 and Br 1-2 were 505-656 μ m. The overall macronutrient composition of buckwheat milling fractions as a raw, uncooked material, is presented in Table II.

TABLE I
Yield of Milling Fractions (% milled grain, db)

Fraction No.	Fine Flour (FF)	Coarse Flour (CF)	Small Semolina (SS)	Big Semolina (BS)	Bran (Br)	Husk (H)	Losses
1	4.8	5.1	2.1	1.8	1.7	27.6	...
2	2.7	3.5	3.5	2.1	2.2	...	...
3	2.2	2.9	2.6	...	1.8	...	...
4	1.9	...	2.4	...	2.7	...	...
5	6.1	...	...	...	2.4	...	...
6	2.9	...	...	...	3.5	...	...
7	3.0	...	...	...	...	...	...
Total	23.6	11.5	10.6	3.9	14.3	27.6	8.5

TABLE II
Nutrient Composition of Buckwheat Milling Fractions

Fraction ^a	Starch (% db)	Crude Proteins (% db)	Fat (% db)	Ash (% db)	Rutin (ppm)	Phytate (% db)	Tannin (% db)	P (mg/100 g)	Fe (mg/100 g)
FF1	91.7	4.6	0.5	0.6	22.5	0.2	0.1	80	7.6
FF2	90.4	4.5	0.9	0.9	19.2	0.3	0.1	89	16.3
FF3	90.0	5.0	1.0	0.8	22.9	0.3	0.1	95	15.6
FF4	87.2	5.7	0.8	1.1	37.6	0.4	0.1	149	19.1
FF5	89.8	4.4	0.7	0.9	19.4	0.3	0.1	103	23.8
FF6	82.4	7.7	1.7	1.7	81.6	0.7	0.2	296	21.9
FF7	70.4	11.9	3.3	2.7	168.2	0.7	0.3	541	17.5
CF1	84.4	6.8	1.8	1.0	74.2	0.6	0.4	224	13.3
CF2	86.4	6.4	1.4	1.4	57.3	0.5	0.3	193	14.0
CF3	83.0	7.5	1.4	1.7	77.9	0.7	1.2	241	23.3
SS1	66.9	12.5	3.7	2.7	159.7	0.6	1.0	550	23.4
SS2	69.3	11.5	3.0	2.7	131.9	0.6	0.7	522	26.4
SS3	63.0	16.1	4.3	3.5	192.2	0.5	0.8	672	18.2
SS4	55.3	18.7	5.5	4.1	259.5	0.5	1.7	849	20.8
BS1	66.0	13.4	8.9	3.1	194.9	0.6	1.4	608	23.8
BS2	50.6	18.8	5.4	4.3	236.2	0.5	2.2	845	16.7
Br1	34.6	26.7	8.0	5.6	326.8	0.5	2.9	1,319	12.5
Br2	29.2	27.7	8.8	5.6	385.1	0.3	4.1	1,298	17.5
Br3	42.6	19.2	4.6	4.2	439.4	0.4	3.0	882	22.1
Br4	42.2	23.9	7.0	5.4	332.8	0.4	3.1	1,120	13.0
Br5	25.5	30.0	8.9	6.7	476.9	0.3	3.1	1,502	14.8
Br6	20.3	31.3	9.7	6.5	475.5	0.3	6.0	1,512	18.1
H	0.5	3.7	0.4	1.3	29.5	0.0	0.3	na ^b	na

^a Fine flour (FF), coarse flour (CF), small semolina (SS), big semolina (BS), bran (Br), Husk (H).

^b Not analyzed.

Starch and Protein

In milling fractions, the starch content was 20.3–91.7% (db). However, samples ranked as FF and CF were richest in this component. Except for FF 7, all flour samples contained >80% starch (db). In SS, BS, and especially in Br fractions, there was significantly less starch, while the husk fraction had a negligible amount of this particular nutrient ($\approx 0.5\%$) existed.

The results on starch concentration in the 23 fractions studied here are somewhat different from those obtained in 11 milling fractions studied by Steadman et al (2001b), who reported 10.2% starch as the lowest and 75.5% starch as the highest content.

Starch incorporated in whole dehulled buckwheat seed (groats) to some extent resists amyolytic attack and is also exposed to retrogradation processes on storage as recently shown in vitro and in vivo with rats (Skrabanja and Kreft 1998; Skrabanja et al 1998, 2000). Also, a study on healthy humans revealed that certain buckwheat products flatten metabolic responses such as blood glucose and insulin after ingestion, especially when whole groats were included in the tested food portion (Skrabanja et al 2001).

However, when buckwheat is milled to flour and then thermally treated (as in buckwheat bread), the starch appears to be easily degraded by amyolytic enzymes, but not as rapidly as in comparable wheat products (Skrabanja et al 2001; Kreft and Skrabanja 2002). There is a suggestion that buckwheat contains one or more compounds that inhibit α -amylase, possibly protein (Ikeda et al 1994) or more stable compounds such as tannins and phytic acid (Luthar 1992; Hong et al 1996; Steadman et al 2001a).

The distribution of proteins is different from the distribution of starch (Table II). The maximum value (31.3%, db) was found in Br6, while FF samples were relatively poor in protein. Only a small difference appeared between the lowest content of protein in FF (4.4%, db, in FF 5) and H fraction (3.7%, db). Correlation between starch and proteins is negative and highly significant ($r = -0.9940$, $P = 0.0000$).

The protein content in buckwheat seeds depends on a variety of ecological factors during growth (Mazza 1993). Differences in protein content between different kernel parts were noticeable. Whole kernel contains 13.8%, groat 16.4%, germ >50%, and hulls only 4% protein (Pomeranz and Robbins 1972). The results for protein were 4.4–31.3% (db) and are in good agreement with those for 10 milling fractions published by Kreft et al (1994) and for 11 fractions examined by Steadman et al (2001b).

Beside starch, proteins are the main endogenous factor responsible for the textural characteristics of buckwheat products (Ikeda et al 1997). Correlations between protein content and hardness, cohesiveness, adhesiveness, springiness, and chewiness evaluated on buckwheat dough prepared from the same fractions were published earlier (Ikeda et al 1999). All textural characteristics, except adhesiveness, had a significantly negative correlation to protein content. Choosing the appropriate ratio between starch and protein content is thus an important aspect when making and designing different buckwheat products.

From the nutritional point of view, the biological value of buckwheat proteins (BV 86) (Skrabanja et al 2000) appeared to be much higher than that of cereal proteins (BV 62–67) (Eggum 1980). Buckwheat proteins may prevent gallstone formation more strongly than soy protein products, retard mammary carcinogenesis by lowering serum estradiol, and suppress colon carcinogenesis by reducing cell proliferation (Kayashita et al 1999; Tomotake et al 2000; Liu et al 2001). This may be explained by the relatively low protein digestibility in buckwheat (Ikeda et al 1986; Ikeda and Kishida 1993; Skrabanja et al 2000). The high content of protein in some buckwheat milling fractions suggests a potential application for these fractions for special dietary products preventing gallstones and mammary carcinogenesis, if the effects are further confirmed. Tannin-protein complexes are potent radical cation scavengers in the gastrointestinal tract and may act as a radical sink (Riedel and Hagerman 2001). As buckwheat does not contain gluten, it is a common supplement for patients with celiac disease (Skerritt 1986; Wieslander and Norbäck 2001).

Fats

Similarly to proteins, fats were also most concentrated in bran and semolina fractions (Table II). In the edible fractions (all except H), the highest value was obtained in Br6 (9.7%, db) and the lowest in FF 1 (0.5%, db). In H fraction, only 0.4% fat (db) was found. The shelf life of buckwheat flour depends largely on the fat content, which is, in general, higher than that in wheat flour (Kreft 1995). Lipids in buckwheat seed are mainly concentrated in embryo and can reach values up to 14% (embryo, db) (Dorrel 1971; Mazza 1993; Kreft and Kreft 1999). There is a high positive correlation of fat content with proteins ($r = 0.9289$; $P = 0.0000$); and a high negative correlation with starch ($r = -0.9221$; $P = 0.0000$).

TABLE III
Soluble Dietary Fiber (DF), Insoluble Dietary Fiber, Total Dietary Fiber, and % Soluble Dietary Fiber in Total Dietary Fiber

Fractions ^a	Soluble DF	Insoluble DF	Total DF	Soluble DF (% db)
FF1	2.4	0.7	3.1	76.5
FF2	1.5	1.8	3.3	44.8
FF3	2.1	0.9	3.1	69.7
FF4	3.1	1.4	4.5	69.2
FF5	1.9	0.8	2.7	71.3
FF6	4.3	2.5	6.8	63.3
FF7	3.8	4.4	8.1	46.4
CF1	5.5	2.2	7.7	71.5
CF2	1.4	3.0	4.4	32.5
CF3	2.7	1.7	4.3	60.2
SS1	2.7	3.9	6.6	40.4
SS2	4.5	5.0	9.6	47.4
SS3	2.0	6.4	8.4	24.2
SS4	3.1	6.8	9.9	31.3
BS1	3.6	5.9	9.6	38.1
BS2	3.6	9.3	12.9	27.7
Br1	3.9	13.0	17.0	23.2
Br2	4.1	14.4	18.5	22.1
Br3	2.4	15.8	18.2	13.0
Br4	4.8	10.6	15.4	31.0
Br5	4.3	12.8	17.1	25.2
Br6	6.6	14.8	21.3	30.8
H	2.7	89.1	91.8	2.9

^a Fine flour (FF), coarse flour (CF), small semolina (SS), big semolina (BS), bran (Br), Husk (H).

Ash and Minerals

Much less ash was found in FF 1 than in any other milling fraction (0.6%, db). Also, <1% ash was found in FF 2, 3, and 5, and in CF 1. In semolina and in bran fractions, the percentage of ash was the highest, the 6.7% (db) value is maximal (Table II). The ash content in the husk fraction (1.3%, db) is not exceptional.

It is interesting to see the values of iron for flours, which range from 7.6 (FF 1) to 23.8 (FF 5) mg/100 g, db (Table II). These values overlap with values of other milling fractions. The correlation of Fe with starch and with proteins is nonsignificant ($r = 0.0625$ ns, $r = -0.1173$ ns, respectively). However, there is a marginally significant correlation between iron and phytate contents ($r = 0.4251$; $P = 0.0486$).

The content of mineral elements (except iron) in the fractions studied was reported previously (Ikeda et al 2000). Huge variations for a particular mineral element can be found among milling fractions. However, in general, semolina and bran fractions are richer in mineral elements than the flour fractions. In particular, the Br 6 fraction contained the highest levels of all minerals, except calcium and iron, while FF 1 fraction had the lowest concentration of elements, with no exception.

Dietary Fiber

In buckwheat milling fractions (except husks) the overall range in total dietary fiber was 2.7–21.3% (db). In husks, the fiber content was >90%, but the proportion of soluble dietary fiber was relatively small (2.9%, db). Flour fractions contained lower amounts of total dietary fiber (2.7–8.1%, db) than semolina (6.6–12.9%, db) or bran fractions (15.4–21.3%, db). In general, the soluble dietary fiber content appeared to be more constant across different kernel parts (1.4–6.6%, db) than that of insoluble fiber (0.7–15.8%, db). The grouping of milling fractions showed that the percentage of soluble dietary fiber in total dietary fiber is much higher in flours than in semolina or bran fractions (Table III).

Wasik (1977) reported that buckwheat flour contains 0.4% fiber (0.44%, db), bran 4.1% (4.5%, db) and hulls (husks) 50.2% (54.6%, db). Later, because of a more physiological approach to dietary fiber analysis, the published results were much higher. Steadman et al (2001a,b) determined total dietary fiber in flour and bran, at 1.7%–40.3%, respectively. In our case, a narrower range of total dietary fiber content was established. This suggests that an informed choice of milling fractions might provide an organism with the desired amount of dietary fiber. Moreover, it is also possible to choose the appropriate ratio of soluble to total dietary fiber in buckwheat milling fractions. Keeping in mind that soluble fiber has the potential to reduce total cholesterol concentrations, mainly by lowering LDL cholesterol (He et al 1995), fractions such as FF 6, CF 1, and SS 2 should be of interest when designing products for dietary treatment of cardiovascular disorders.

Tannin, Rutin and Phytate Content

The highest concentration of tannin in Br was significant, amounting to 5.95%, db, in the Br 6 fraction. The lowest values for tannin were obtained in FF and H fractions. From a nutritional point of view, the report that polyphenols naturally present in buckwheat husks may lower the true digestibility of buckwheat proteins should be taken into consideration (Skrabanja et al 2000). As published by Ikeda et al (1986), tannic acid and catechin exhibited significant inhibitory effects on the in vitro peptic and pancreatic digestion of buckwheat globulin. The antioxidant activity of buckwheat polyphenols was demonstrated (Watanabe 1998), and positive effects of buckwheat polyphenols in counteracting cardiovascular problems have been confirmed by epidemiological and clinical studies (Schilcher et al 1990). Rutin content was lowest at 19 ppm in flour (FF 2) up to 477 ppm in bran (Br 5).

Phytate was present in milling fractions (husks not taken into account) at 0.21%–0.72%; these extreme values were found within FF samples. Phytate is the most evenly distributed constituent among

milling fractions. Interestingly, phytate is not in good correlation with any other substance, but it has a unique distribution (Table II). In one group of milling fractions (husk, bran and semolina fractions), there was a significant positive correlation between phytate and starch content. Thus, when starch content rise from zero (husk) to ≈70% in semolina fractions, phytate content changed from <0.1% in husk to ≈0.6% in semolina. In contrast to this, there is a negative relationship between phytic acid and starch content in flour fractions. With more starch (from ≈80% to >90%), the phytate content decreases (≈0.7%–0.2%).

Color Values

Lightness (L^*) of buckwheat milling fractions was scored numerically on a chromameter (Table IV) and showed a significantly positive correlation ($r = 0.917$, $P \leq 0.001$) with starch, meaning that the higher the proportion of starch, the lighter the fraction color.

Parameters a^* and b^* correlated similarly to components assayed in buckwheat milling fractions. There is no correlation of a^* and b^* to soluble dietary fiber, phytic acid, or Fe content. Values a^* and b^* correlated negatively with starch content, while other correlations of these two color parameters to the rest of the components in buckwheat milling fractions were positive. The more green and blue parts of spectra prevailed in starchy fractions.

CONCLUSIONS

Milling buckwheat kernels to obtain many different fractions may have several advantages. It may lead to the concentration of some interesting components (for example, soluble dietary fiber, proteins, and polyphenols) in certain milling fractions. Components responsible for technological properties may also be concentrated or regulated to obtain a desired end-use product. Functionality of such products is very important. Depending on a metabolic or physiological need of a patient, the appropriate fraction may be chosen to achieve the desired effect.

Certainly, it would be worth supporting the present data by the physiological or epidemiological studies that could confirm and demonstrate a relevant relationship between the intake of a particular milling fraction and a specific physiological benefit.

TABLE IV
Color Values^a L^* , a^* , and b^* of Buckwheat Milling Fractions

Fraction ^b	L^*	a^*	b^*
FF1	88.8	-0.9	6.2
FF2	88.0	-0.9	6.5
FF3	88.4	-0.9	6.6
FF4	87.2	-0.8	7.0
FF5	89.0	-1.2	6.8
FF6	86.2	-1.0	8.3
FF7	84.5	-0.9	9.4
CF1	84.5	-1.0	7.6
CF2	86.0	-1.0	7.7
CF3	85.7	-1.1	8.6
SS1	78.8	-1.0	11.3
SS2	79.5	-1.0	11.6
SS3	78.0	-1.1	12.3
SS4	75.9	-0.9	13.0
BS1	74.2	-0.7	12.4
BS2	70.9	-0.3	13.0
Br1	71.1	-0.6	14.1
Br2	69.3	-0.3	13.6
Br3	67.8	-0.3	10.9
Br4	75.1	-0.8	13.1
Br5	73.8	-0.7	13.6
Br6	72.0	-0.6	13.5
H	43.1	1.6	6.2

^a L^* indicates lightness, a^* and b^* indicate hue and chroma (a^* green to red and b^* blue to yellow).

^b Fine flour (FF), coarse flour (CF), small semolina (SS), big semolina (BS), bran (Br), Husk (H).

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LITERATURE CITED

- Anonymous. 1998. Functional food science in Europe. *Br. J. Nutr.* 80(Suppl. 1):193
- Anonymous. 1999. Scientific concepts of functional foods in Europe: Consensus Document. *Br. J. Nutr.* 81(Suppl. 1):27.
- AOAC. 1990. Official Methods of Analysis of the Association of the Official Analytical Chemists. 16th Ed. The Association: Arlington, VA.
- CIE. 1971. Colorimetry, Official Recommendations of the International Commission of Illumination, Commission Internationale de l'Éclairage, Publication N. 15 (E.1.3.1.). Bureau Central de la C.I.E.: Paris.
- Dorrel, D. G. 1971. Fatty acid composition of buckwheat seed. *J. Am. Oil Chem. Soc.* 48:693-696.
- Earp, C. F., Akingbala, J. O., Ring, S. H., and Rooney, L. W. 1981. Evaluation of several methods to determine tannins in sorghums with varying kernel characteristics. *Cereal Chem.* 58:234-238.
- Eggum, B. O. 1980. The protein quality of buckwheat in comparison with other protein sources of plant or animal origin. Pages 115-120 in: Symposium on Buckwheat. I. Kreft, B. Javornik, and B. Vombergar, eds. Biotechnical Faculty, University of Ljubljana: Ljubljana, Slovenia.
- Fiske, C. H., and Subbarow, Y. 1925. The colorimetric determination of phosphorus. *J. Biol. Chem.* 66:375-400.
- Griffith, J. Q., Couch, J. F., and Lindauer, A. 1944. Effect of rutin on increased capillary fragility in man. *Proc. Soc. Exp. Biol. Med.* 55:228-229.
- Hagels, H., Wagenbreth, D., and Schilcher, H. 1995. Phenolic compounds of buckwheat herb and influence of plant and agricultural factors (*Fagopyrum esculentum* Moench and *Fagopyrum esculentum* Gärtner). Pages 801-809 in: Current Advances in Buckwheat Research. Proc. 6th Int. Symp. on Buckwheat. Vol. II. T. Matano, A. Ujihara, eds. Shinshu University Press: Shinshu, Japan.
- Haug, W., and Lantsch, H.-J. 1983. Sensitive method for the rapid determination of phytate in cereals and cereal products. *J. Sci. Food Agric.* 34:423-426.
- He, J., Klag, M. J., Whelton, M. J., Mo, J.-P., Chen, J.-Y., Qian, M.-C., Mo, P.-S., and He, G.-S. 1995. Oats and buckwheat intakes and cardiovascular disease risk factors in an ethnic minority in China. *Am. J. Clin. Nutr.* 61:366-372.
- Hong, J.-H., Ikeda, K., Kreft, I., and Yasumoto, K. 1996. Near-infrared diffuse reflectance spectroscopic analysis of the amounts of moisture, protein, starch, amylose, and tannin in buckwheat flours. *J. Nutr. Sci. Vitaminol.* 42:359-366.
- Ikeda, K., and Kishida, M. 1993. Digestibility of proteins in buckwheat seed. *Fagopyrum* 13:21-24.
- Ikeda, S., and Yamashita, Y. 1994. Buckwheat as a dietary source of zinc, copper and manganese. *Fagopyrum* 14:29-34.
- Ikeda, K., Oku, M., Kusano, T., and Yasumoto, K. 1986. Inhibitory potency of plant antinutrients towards the in vitro digestibility of buckwheat protein. *J. Food Sci.* 51:1527-1530.
- Ikeda, K., Shida, K., and Kishida, M. 1994. α -Amylase inhibitor in buckwheat seed. *Fagopyrum* 14:3-6.
- Ikeda, K., Kishida, M., Kreft, I., and Yasumoto, K. 1997. Endogenous factors responsible for the textural characteristics of buckwheat products. *J. Nutr. Sci. Vitaminol.* 43:101-111.
- Ikeda, K., Fujiwara, J., Asami, Y., Arai, R., Bonafaccia, G., Kreft, I., and Yasumoto, K. 1999. Relationship of protein to the textural characteristics of buckwheat products: analysis with various buckwheat flour fractions. *Fagopyrum* 16:79-83.
- Ikeda, S., Yamashita, Y., and Kreft, I. 2000. Essential mineral composition of buckwheat flour fractions. *Fagopyrum* 17:57-61.
- James, C. S. 1995. Analytical Chemistry of Foods. Chapman & Hall: London.
- Kayashita, J., Shimaoka, I., Nakajoh, M., Kishida, N., and Kato, N. 1999. Consumption of a buckwheat protein extract retards 7,12-dimethylbenz[alpha]anthracene-induced mammary carcinogenesis in rats. *Biosci. Biotechnol. Biochem.* 63:1837-1839.
- Kreft, I. 1995. Ajda. CZD, Kmecki glas: Ljubljana Slovenia.
- Kreft, I., and Škrabanja, V. 2002. Nutritional properties of starch in buckwheat noodles. *J. Nutr. Sci. Vitaminol.* 48:47-50.
- Kreft, I., Bonafaccia, G., and Zigo, A. 1994. Secondary metabolites of buckwheat and their importance in human nutrition. *Prehrambeno-tehnolška Biotehnolška Revija* 32:195-197.
- Kreft, M., and Kreft, S. 1999. Computer aided three-dimensional reconstruction of the buckwheat (*Fagopyrum esculentum* Moench) seed morphology. *Res. Rep. Agric.* 73:331-336.
- Kreft, S., Knapp, M., and Kreft, I. 1999. Extraction of rutin from buckwheat (*Fagopyrum esculentum* Moench) seeds and determination by capillary electrophoresis. *J. Agric. Food Chem.* 47:4649-4652.
- Liu, Z., Ishikawa, W., Huang, X., Tomotake, H., Kayashita, J., Watanabe, H., Nakajoh, M., and Kato, N. A. 2001. Buckwheat protein product suppresses 1,2-dimethylhydrazine-induced colon carcinogenesis in rats by reducing cell proliferation. *J. Nutr.* 131:1850-1853.
- Luthar, Z. 1992. The content and the distribution of tannin in the BW seeds (*Fagopyrum esculentum* Moench). PhD thesis. University of Ljubljana: Ljubljana, Slovenia.
- Matissek, R., Schnepel, F.-M., and Steiner, G. 1992. Lebensmittelanalytik: Grundzüge, Methode, Anwendungen. 2. Auflage. Springer-Verlag: Berlin.
- Mazza, G. 1993. Buckwheat. Pages 516-521 in: Encyclopaedia of Food Science, Food Technology and Nutrition. Vol. 1, R. Macrae, R. K. Robinson, M. J. Sadler, eds. Academic Press: New York.
- Modic, M. 1998. Evaluation of selenium contents and distribution in samples of buckwheat. Doctoral thesis. University of Ljubljana: Slovenia, Ljubljana.
- Park, C. H., Kim, Y. B., Choi, Y. S., Heo, K., Kim, S. L., Lee, K. C., Chang, K. J., and Lee, H. B. 2000. Rutin content in food products processed from groats, leaves and flowers of buckwheat. *Fagopyrum* 17:63-66.
- Pomeranz, Y., and Robbins, G. S. 1972. Amino acid composition of buckwheat. *J. Agric. Food Chem.* 20:270-274.
- Prosky, L., Asp, N.-G., Furda, I., De Vries, J. W., and Schweizer, T. F. 1985. Vitamins and other nutrients. Determination of total dietary fiber in food and food products: Collaborative study. *JAOAC* 68:667-679.
- Prosky, L., Asp, N.-G., Schweizer, T. F., Devries, J. W., and Furda, I. 1988. Determination of insoluble, soluble and total dietary fibre in food and food products interlaboratory study. *JAOAC* 71:1017-1023.
- Riedel, K. M., and Hagerman, A. E. 2001. Tannin-protein complexes as radical scavengers and radical sinks. *J. Agric. Food Chem.* 49:4917-4923.
- Schilcher, H., Patz, B., and Schimmel, K. Ch. 1990. Klinische Studie mit einem Phytopharmakon zur Behandlung von Mikrozirkulationsstörungen. *Arztezeitschrift für Naturheilverfahren* 31:819-826.
- Skerritt, J. H. 1986. Molecular comparison of alcohol-soluble wheat and buckwheat proteins. *Cereal Chem.* 63:365-369.
- Skrabanja, V., and Kreft, I. 1998. Resistant starch formation following autoclaving of buckwheat (*Fagopyrum esculentum* Moench) groats. An in vitro study. *J. Agric. Food Chem.* 46:2020-2023.
- Skrabanja, V., Laerke, H. N., and Kreft, I. 1998. Effects of hydrothermal processing of buckwheat (*Fagopyrum esculentum* Moench) groats on starch enzymatic availability in vitro and in vivo in rats. *J. Cereal Sci.* 28:209-214.
- Skrabanja, V., Laerke, H. N., and Kreft, I. 2000. Protein-polyphenol interactions and in vivo digestibility of buckwheat groat proteins. *Pflügers Archiv. Eur. J. Physiol.* 440:R129-R131.
- Skrabanja, V., Liljeberg Elmståhl, H. G. M., Kreft, I., and Björck, I. M. E. 2001. Nutritional properties of starch in buckwheat products: studies in vitro and in vivo. *J. Agric. Food Chem.* 49:490-496.
- Steadman, K. J., Burgoon, M. S., Lewis, B. A., Edwardson, S. E., and Obendorf, R. L. 2001a. Minerals, phytic acid, tannin and rutin in buckwheat seed milling fractions. *J. Sci. Food Agric.* 81:1094-1100.
- Steadman, K. J., Burgoon, M. S., Lewis, B. A., Edwardson, S. E., and Obendorf, R. L. 2001b. Buckwheat seed milling fractions: Description, macronutrient composition and dietary fiber. *J. Cereal Sci.* 33:271-278.
- Tomotake, H., Shimaoka, I., Kayashita, J., Yokoyama, F., Nakajoh, M., and 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.
- Tovar, J., Björck, I. M., and Asp, N.-G. 1990. Starch content and α -amylolysis rate in precooked legume flours. *J. Agric. Food Chem.* 38:1818-1823.
- Wasik, R. J. 1977. Production of a protein-rich fraction from dehulled buckwheat by conventional roller milling. *Can. Inst. Food Sci. Technol. J.* 10:236-238.
- Watanabe, M. 1998. Catechins as antioxidants from buckwheat (*Fagopyrum esculentum* Moench) groats. *J. Agric. Food Chem.* 46:839-845.
- Wieslander, G., and Norbäck, D. 2001. Buckwheat allergy. *Allergy* 56:703-704.

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