Research paper

Flavonoid concentration in milling fractions of Tartary and common buckwheat

Blanka VOMBERGAR¹, Vida ŠKRABANJA² and Mateja GERM*²

1 Education Centre Piramida Maribor, SI-2000 Maribor, Slovenia
2 Biotechnical Faculty, University of Ljubljana, SI-1000 Ljubljana, Slovenia
* Corresponding author: Mateja Germ, Biotechnical Faculty, University of Ljubljana, SI-1000 Ljubljana, Slovenia

E-mail addresses of authors:
blanka.vombergar@guest.arnes.si, vida.skrabanja@guest.arnes.si, Mateja.Germ@bf.uni-lj.si

DOI https://doi.org/10.3986/fag0013

Received: December 5, 2019; accepted: March 30, 2020
Keywords: common buckwheat, Tartary buckwheat, flavonoids, milling, hydrothermal treatment

ABSTRACT

Common buckwheat (Fagopyrum esculentum Moench) and Tartary buckwheat (F. tataricum Gaertn.) samples were used in milling, sieving and analysing experiments. Flavonoids were analysed in buckwheat samples, in milling and sieving fractions and after the contact of flour particles with water, to simulate conditions in dough.

In Tartary buckwheat, there was even more than 100-times higher content of flavonoids flour in comparison to respective fractions of common buckwheat flour. The highest concentration of flavonoids in milling fractions of Tartary buckwheat flour (granulation over 100 µm up to including 1000 µm) was established as 3.5–4.5% flavonoids/DM.

Immediately after the direct contact of flour particles of common and Tartary buckwheat with water the apparent concentration of flavonoids rose (even for 100% or more) in the first 5–30 minutes of contact. After one hour, due to the degradation of flavonoids, their concentration decreased. Concentration of flavonoids are after 24 hours of contact of flavonoids with water in all milling fractions lower in comparison to the value after first 5 minutes of contact with water.
INTRODUCTION

Buckwheat is used as a food ingredient after husking, milled, prepared at different temperatures and in a diversity of media, predominantly in water. Research imitating real technological process producing foods and dishes from buckwheat are important for evaluating nutritional value of foods based on buckwheat. In buckwheat grain there are important polyphenolic substances, including flavonoids. Among consumers of buckwheat foods and dishes there is growing interest for the composition and nutritional value of products.

Among buckwheat species and cultivars there are differences in content of flavonoids, including rutin. The concentration of flavonoids may depend on genotype, development phases, weather, altitude, year of growing and harvest, storage and other factors. Different plant parts may contain different content of flavonoids. Several authors report higher content of rutin in Tartary buckwheat in comparison to common buckwheat (Suzuki et al., 2002; Fabjan et al., 2003; Lin, 2004; Asami et al., 2007; Fabjan, 2007). There could be as well differences among samples of Tartary buckwheat. Several authors (Fabjan et al., 2003; Briggs et al., 2004; Chai et al., 2004; Park B.J. et al., 2004; Suzuki et al., 2005; Jiang et al., 2007; Ghimeray et al., 2009, Kreft, 2013; Kreft et al., 2013; Kreft et al., 2016ab; Kreft 2016; Germ et al., 2019) report about diverse results on samples of buckwheat. According to Liu in Zhu (2007) the main flavonoid in Tartary buckwheat is rutin, along with querctein and quercitrin (Fabjan, 2007; Morishita et al., 2007). In the grain of common buckwheat there are flavonoids rutin, epicatechin and epicatechingalat. Dietrich-Szostak and Oleszek (1999) isolated from common buckwheat 6 flavonoids, namely rutin, quer млн, orientin, vitexin, isovitexin and isoorientin. Rutin and isovitexin in dehusked buckwheat grain and all 6 of them in husk. Some literature data are presented in Table 1.

Crushing, milling and sieving are the main procedures to obtain buckwheat milling fractions. The gain of flour is in buckwheat normally about 40–50% of the total mass of grain. The rest are husks and peripheral parts of grain (testa, cotyledons). Peripheral parts of grain are crushed differently in comparison to endosperm, and they do not pass the fine sieves. Cotyledons are richer in rutin in comparison to endosperm, so flour may contain less rutin in comparison to the whole grain (Kreft, 1995). The methods of treatment of the grain, like husking, crushing, milling and sieving have an impact on the concentration of flavonoids and other polyphenolic substances. As well as the presence of husk and bran particles in darker flour milling fractions may also have impact on the flavonoids and other polyphenolic substances. Allocation of flavonoids in different parts of buckwheat grain have impact on the utilization value of milling fractions. Know-

| Buckwheat species                  | Sample                          | Flavonoid concentration | Reference                      |
|------------------------------------|---------------------------------|--------------------------|--------------------------------|
| Common buckwheat                   | Grain                           | 24.4 µg/mg               | Ghimeray et al. (2009)          |
| Common buckwheat                   | Grain                           | 0.04%                    | Jiang et al. (2007)             |
| Common buckwheat                   | Grain                           | 18.8 mg/100 g DM         | Dietrich-Szostak in Oleszek (1999) |
| Tartary buckwheat                  | Grain                           | 142.2 µg/mg              | Ghimeray et al. (2009)          |
| Tartary buckwheat                  | Grain                           | 2.04 %                   | Jiang et al. (2007)             |
| Common buckwheat                   | 16 milling fractions            | 2.35–135.4 mg/100 g      | Hung in Morita (2008)           |
| Common buckwheat                   | Flour from shop (Slovenia)      | 0.016                    | Avguštin (2009)                 |
| Common buckwheat                   | Flour                           | 0.0098 %/DM              | Quettler-Deleu et al. (2000)    |
| Common buckwheat                   | Husk                            | 0.0456 %/DM              | Quettler-Deleu et al. (2000)    |
| Common buckwheat (diverse cultivars)| Husk                           | 102.1–151.5 mg/100 g     | Dietrich-Szostak (2004)         |
| Common buckwheat                   | Husk                            | 74 mg/100 g DM           | Dietrich-Szostak in Oleszek (1999) |
| Common buckwheat                   | Bread (mixed: wheat, buckwheat) | 7.76–26.9 mg/kg          | Bojanská et al. (2009)          |
| Tartary buckwheat (Korea)          | Sprouts powder                  | 24 g/kg                  | Gadžo et al. (2009)             |
ledge about the distribution of flavonoids in milling fractions, in the relation to the size of particles (granulation) is of importance for the simple, swift, and efficient way of obtaining flavonoid-rich milling fractions, especially in Tartary buckwheat.

MATERIAL IN METHODS

Material

Common buckwheat (Fagopyrum esculentum Moench) and Tartary buckwheat (F. tataricum Gaertn.) samples were used in milling, sieving and analysing experiments. Two samples (T1 and T2) of Tartary buckwheat were included, obtained from Luxemburg and a sample of common buckwheat (variety Darja, sample D), obtained from Biotechnical faculty, Ljubljana, Slovenia. By milling and sieving of Tartary buckwheat sample T1 and common buckwheat four fractions were obtained with different granulations. Each of them was mixed with water. Sample T2 was obtained as flour, which was sieved into two fractions with different granulation.

Methods

Samples T1 and D were milled by cereal mill Quadromat Junior Model No. 08 801 01 (Brabender Duisburg, Germany), to obtain two fractions by planary sieves (Table 2).

To the flour fractions, water was added and the dough was made. Amount of added water and contact time flour/water prior to freezing is reported in Table 3. Fractions over 1000 µm (T1 F22 and D F22) contained mainly husk and some bran, so they were just rinsed in water (Table 3). After 30 days of storage below, the samples were freeze-dried. By spectrophotometric analyses (spectrophotometer TECAN Genios), using 5% AlCl3 (reaction between flavonoids and AlCl3), which results in yellow colour with maximum at 420 nm (Dutra, 2008; Zhang et al., 2005; Bohm, 1997), concentration of flavonoids was determined. Statistical analyses were performed using Microsoft Excel 2003 and program STAT G (Statgraphics 5.0, Statistical Graphics Corporation, ZDA), and by ANOVA, significance was accepted at p<0.05 (Ferligoj, 1997; Ferligoj and Lozar Manfreda, 2009). All measurements and analyses were performed in three independent samples.

RESULTS

Milling fractions of studied common and Tartary buckwheat samples contained very different amount of flavonoids (Table 4). Concentration of flavonoids was (sample D) much lower in common buckwheat in comparison to Tartary buckwheat (Table 4, Fig. 1.) Comparison of respective fractions of Tartary buckwheat T1 and common buckwheat D (Table 4, Fig. 1.) showed much higher (50 do 100-times higher) concentration of flavonoids in

| Sample | Process | Fractions | Further process | Subfractions | Granulations |
|--------|---------|-----------|----------------|--------------|--------------|
| Tartary buckwheat, grain (T1) | Milling | T1 F1 | Sieving | T1 F11 | ≤ 100 µm |
| | | | | T1 F12 | 100 µm < x ≤ 236 µm |
| | | T1 F2 | Sieving | T1 F21 | 236 µm < x ≤ 1000 µm |
| | | | | T1 F22 | > 1000 µm and bran, husk |
| Common buckwheat Darja, grain (D) | Milling | D F1 | Sieving | D F11 | ≤ 100 µm |
| | | | | D F12 | 100 µm < x ≤ 236 µm |
| | | D F2 | Sieving | D F21 | 236 µm < x ≤ 1000 µm |
| | | | | D F22 | > 1000 µm and bran, husk |
| Tartary buckwheat – flour (T2) | / | / | Sieving | T2 F11 | ≤ 100 µm |
| | | | | T2 F12 | >100 µm |

T1 - Tartary buckwheat, flour from entire grain
D - Common buckwheat Darja, flour from entire grain
T2 - Tartary buckwheat, obtained as flour
Table 3: Dough samples being prepared for freezing

| Sample No. | Sample | Mass (g) | Water addition (mL) | Contact times (flour and water) prior to freezing | Freezing and storage |
|------------|--------|----------|---------------------|-----------------------------------------------|----------------------|
| 1          | T1 F11 | 250      | 200                 | 0.08 h, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h         | 0.5 h: –35 °C to –40 °C; 1 month: –15 °C to –20 °C |
| 2          | T1 F12 | 125      | 100                 | SAME                                          | SAME                 |
| 3          | T1 F21 | 100      | 130                 | SAME                                          | SAME                 |
| 4          | T1 F22 | 125      | 200                 | SAME                                          | SAME                 |
| 5          | D F11  | 250      | 200                 | 0.08 h, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h         | 0.5 h: –35 °C to –40 °C; 1 month: –15 °C to –20 °C |
| 6          | D F12  | 250      | 200                 | SAME                                          | SAME                 |
| 7          | D F21  | 250      | 235                 | SAME                                          | SAME                 |
| 8          | D F22  | 250      | 400                 | SAME                                          | SAME                 |
| 9          | T2 F1  | 250      | 200                 | 0.08 h, 1 h, 2 h, 4 h, 8 h, 12 h, 24 h         | 0.5 h: –35 °C to –40 °C; 1 month: –15 °C to –20 °C |
| 10         | T2 F11 | 200      | 160                 | SAME                                          | SAME                 |
| 11         | T2 F12 | 200      | 160                 | SAME                                          | SAME                 |

T1 - Tartary buckwheat, whole grain flour
D - Common buckwheat Darja (from grain)
T2 F1 - Tartary buckwheat flour

Table 4: Comparison of flavonoid content in milling fractions of Tartary and common buckwheat (samples T1, T2, D) and in milling fractions with added water after 5 minutes and after 24 hours of flour-water contact

| Sample               | Subfraction | Milled sample | Dough (flour and water) 0.08 h (5 min) | Dough (flour and water) 24 h |
|----------------------|-------------|---------------|----------------------------------------|----------------------------|
| Tarty buckwheat (T1) | T1 F11      | 0.709         | 1.444                                  | 1.112                      |
| Tarty buckwheat (T1) | T1 F12      | 4.470         | 4.766                                  | 4.311                      |
| Tarty buckwheat (T1) | T1 F21      | 3.542         | 4.262                                  | 3.551                      |
| Tarty buckwheat (T1) | T1 F22      | 0.178         | 0.178                                  | 0.062                      |
| Common buckwheat D   | D F11       | 0.015         | 0.017                                  | 0.006                      |
| Common buckwheat D   | D F12       | 0.043         | 0.085                                  | 0.042                      |
| Common buckwheat D   | D F21       | 0.051         | 0.088                                  | 0.069                      |
| Common buckwheat D   | D F22       | 0.055         | 0.071                                  | 0.055                      |
| Tarty buckwheat (T2) | T2          | 0.916         | 1.226                                  | 0.955                      |
| Tarty buckwheat (T2) | T2 F11      | 0.243         | 0.363                                  | 0.199                      |
| Tarty buckwheat (T2) | T2 F12      | 1.011         | 2.639                                  | 2.063                      |

T1 - Tartary buckwheat (from grain)
D - Common buckwheat Darja (from grain)
T2 - Tartary buckwheat (from flour)
DM - dry matter
Figure 1: Comparison of flavonoid content in milling fractions of common and Tartary buckwheat

Tartary buckwheat milling fractions in comparison to respective common buckwheat milling fractions. However, among fractions, containing mainly husk and bran, in Tartary buckwheat it was only about 3 times more flavonoids at Tartary buckwheat in comparison to common buckwheat. In the investigated samples the highest concentration of flavonoids was in the range 3.5–4.5% in dry matter in milling fractions of Tartary buckwheat T1 (with granulation over 100 µm, including up to 1000 µm). These are milling fractions of dark coarse flours. Fraction of Tartary buckwheat husk had low content of flavonoids. Interestingly, husk fraction of common buckwheat had a high content of flavonoids, in comparison to other milling fractions of common buckwheat.

Concentration of flavonoids was different between two samples of Tartary buckwheat (Table 4, Fig. 1). In comparison of two fine milled light Tartary buckwheat flours (T1 in T2) with the same granulation (up to including 100 µm) we established different content of flavonoids (Table 4, Fig. 1), in both cases the concentration of flavonoids was very low. Comparison of Tartary buckwheat sample T1 and common buckwheat D showed different allocation of flavonoids among milling fractions (Fig. 1). In the Table 4 it was reported that in common buckwheat milling fractions with the granulation up to 100 µm it was much less flavonoids in comparison to fractions over 100 µm. Highest concentration was in the fraction F22 (husk and bran), and lowest in the fraction of light flour F11.

It was studied the content of flavonoids in the dough, made from different milling fractions of Tartary and common buckwheat (samples T1, T2, D) after first 5 minutes, and up to 24 hours of contact of flour particles with added water (Table 5; Fig. 1).
Impact of water on the flavonoids concentration was similar for common and Tartary buckwheat (Figs. 2 and 3, Table 4). Apparent flavonoid concentration in most of milling fractions rose for about 2 times in the first five minutes after the addition of water, in comparison to untreated, dry samples. The highest elevation was in flavonoids concentration in coarse and fine flours (coarse and fine), and somewhat less in fractions with bran and husk. With few exceptions, it was gradually decreased during 24 hours of contact of flour particles with water. Gradual lowering of flavonoid concentration in the time 0.08 to 24 hours was different among samples and fractions, but lowering from apparent flavonoid concentration in the time 0.08 to 24 hours was a general appearance, it was a linear correlation among time and flavonoid concentration ($r^2 = 0.9953; p<0.05; y = -0.0733 + 0.8739x$). Only in the fraction of bran and husk ($F_{22}$) flavonoids concentration was after 24-hours of contact of particles with water as low as 60 %, in comparison to starting concentration before the addition of water.

**DISCUSSION**

From the point of view of functionality most interesting are milling fractions with the granulation over 100 µm up to including 1000 µm (the milling gain of these fractions is about 30%); from point of view of nutritional functionality less interesting fractions are fine light flours with the granulation below 100 µm (in milling the gain of light flours is nearly about 50%), as they are poor in flavonoids, and also contain low concentration of proteins and minerals (Vombergar, 2010). Collection and mixing of fractions (with the granulation over 100 µm up to including 1000 µm), especially in Tartary buckwheat is the best possibility to obtain flour material rich in flavonoids, proteins and minerals.

Figure 2: Flavonoid concentrations in dough from different milling fractions of Tartary buckwheat (T1) over a 24-hour time period

- **T1 F_{11}**: Tartary buckwheat, granulation ≤ 100 µm
- **T1 F_{12}**: Tartary buckwheat, granulation 100 µm < x ≤ 236 µm
- **T1 F_{21}**: Tartary buckwheat, granulation 236 µm < x ≤ 1000 µm
- **T1 F_{22}**: Tartary buckwheat, granulation > 1000 µm including bran and husk
- 0.08: 5 minutes; 0.5 - 30 minutes, 1 – one hour; 2,4,8,12,24 – hours of contact with water
Highest concentration of flavonoids was established in Tartary buckwheat T1 in milling fractions with the granulation over 100 up to 1000 µm (fractions F12 and F21), namely 3.54–4.47% (Table 4). This is about 100-times more in comparison to the concentration of flavonoids in common buckwheat Darja with the same granulation groups (0.043–0.051%) (Table 4, Fig. 1). The results are in line with previous results about the difference in flavonoid concentration in common and Tartary buckwheat (Piao in Li, 2001; Škrabanja et al., 2004; Hung in Morita, 2008).

It was established that in common buckwheat it is not similar distribution of flavonoids among fractions as in the case of Tartary buckwheat (Table 4, Fig. 1). In common buckwheat it is the richest with flavonoids the fraction of bran and husk F22 with granulation over 1000 µm (DF22 0.055 % flavonoids), what was not the case in Tartary buckwheat. This is the reason for the intensive research of the concentration of flavonoids, especially rutin, in the husk of common buckwheat (Oomah in Mazza, 1996; Watanabe et al., 1997; Dietrych-Szostak and Oleszek, 1999; Kreft et al., 1999; Quettier-Deleu et al., 2000; Steadman et al., 2001b; Dietrych-Szostak, 2004). We detected lower difference in the content of flavonoids between common and Tartary buckwheat in the fraction of husk, than between fractions of flours. So, we suggest the possibility for using of husk of common buckwheat as a source of flavonoids, especially in areas, where Tartary buckwheat is not a traditional crop, as they grow common buckwheat.

Milling affects the release of flavonoids during the extraction of buckwheat polyphenols. Size of particles is an important characteristic of flours. Smaller particles have relatively higher surface area, so the action of enzymes could be different in comparison to crude flour particles. Enzymes in fine milled flours with small particles could be more active. Polyphenols are included in many cell components. So, their extraction to the liquid phase could be different.
Suzuki et al. (2002) and Yasuda (2001, 2007) are reporting about the enzyme flavonol-3-glukosidase, important for the degradation of rutin in buckwheat under certain conditions. This enzyme is located in grain in the testa and cotyledons. Predominant amount of enzyme is in cotyledons, but more active is enzyme stored in testa (Suzuki et al., 2002). Rutin is degraded to quercetin. Suzuki et al. (2004) reported about the correlation of enzyme concentration in buckwheat flour with the concentration of water soluble acids. Mukasa et al. (2009) established that rutin in the husked round formed buckwheat grain is degraded quickly but it is not the case in soaked intact grain. It is supposed that this is due to structural isolation of rutin to the rutin degraded enzymes.

There are different ways of rutin degradation, for example the oxidation of rutin and some other biochemical reactions, transferring rutin to other metabolites. Enzymes, degrading rutin could be blocked in their function. Steaming, cooking and extruding preserve a part of rutin and may prevent the appearance of bitter taste (Pauličková et al., 2004). Mukasa et al. (2009) confirmed that most of rutin remain in grain after cooking one hour. Thermal treatment may have impact on the degradation of flavonoids according to Dietrych-Szostak in Oleszek (1999). Şensoy et al. (2006) reported that roasting, treatment with dry hot air, has no impact on antioxidative properties of light or dark buckwheat flour.

Simulation of technological process of dough making (contact of flour with water) revealed the biochemical events, with impact to some dough constituents (mainly flavonoids – rutin and quercetin).

**CONCLUSION**

In regard to functional aspect and nutritional value are most interesting buckwheat milling fractions with granulation over 100 µm up to including 1000 µm (milling gain about 30%); less interesting are fractions of light fine flours with granulation less than 100 µm (milling gain nearly 50%), which does not contain much proteins, minerals and flavonoids. Collecting and mixing of fractions with granulation over 100 µm up to including 1000 µm, especially at Tartary buckwheat is the best possibility to get flour of high nutritional and functional value, because of flavonoids, proteins and minerals.

Tartary buckwheat has a much higher content of flavonoids in comparison to common buckwheat, even more than 100-times more in Tartary buckwheat flour in comparison to common buckwheat flour. The highest concentration of flavonoids in milling fractions of Tartary buckwheat flour T1 (granulation over 100 µm up to including 1000 µm) was established as 3.5–4.5% flavonoids/DM.

Flavonoids in milling fractions with different granulation are differently allocated. Allocation is different in Tartary buckwheat and common buckwheat.

Immediately after the direct contact of flour particles of common and Tartary buckwheat with water the apparent concentration of flavonoids rose (even for 100% or more) in the first 5–30 minutes of contact. After one hour, due to the degradation of flavonoids, their concentration became lower. Concentration of flavonoids are after 24 hours of contact of flavonoids with water in all milling fractions lower in comparison to the value after first 5 minutes of contact with water.

**REFERENCES**
Asami Y., Arai R., Lin R., Honda Y., Suzuki T., Ikeda K. 2007. Analysis of components and textural characteristics of various buckwheat cultivars. FAGOPYRUM, 24: 41–48
Avguštin M. 2009. Analiza vsebnosti antioksidantov in fagopirina v ajdovih kalčkih. Diplomsko delo. Ljubljana, Univerza v Ljubljani, Fakulteta za farmacijo: 54 str.
Bojňanská T., Frančáková H., Chlebo P., Vollmannová A. 2009. Rutin content in buckwheat enriched bread and influence of its consumption on plasma total antioxidant status. Czech Journal of Food Science, Special Issue, 27: S236–S240.
Bohm B. 1998. Introduction to Flavonoids. Volume 2. Chemistry and Biochemistry of Organic Natural Products. Amsterdam, Harwood Academic Publishers: 503 str.
Briggs C. J., Campbell C., Pierce G., Jiang P. 2004. Bioflavonoid analysis and antioxidant properties of tartary buckwheat accessions. V: Advances in Buckwheat Research. Proceeding of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 593–597
Chai Y., Feng B., Hu Y. G., Gao J., Gao X. 2004. Analysis on the variation of rutin content in different buckwheat genotypes. V: Advances in Buckwheat Research. Proceeding of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 688–691
Dietrych-Szostak D., Oleszek W. 1999. Effect of processing on the flavonoid content in buckwheat (Fagopyrum esculentum Moench) grain. Journal of Agricultural and Food Chemistry, 47: 4384–4387

Dietrych-Szostak D. 2004. Flavonoids in hulls of different varieties of buckwheat and their antioxidant activity. V: Advances in Buckwheat Research. Proceeding of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 621–625

Dutra R. C., Leite M. N., Barbosa N. R. 2008. Quantification of phenolic constituents and antioxidant activity of Pterodon emarginatus vogel seeds. International Journal of Molecular Sciences, 9: 606–614

Fabjan N. 2003. Zel in zrnje tatarske ajde kot vir flavonoidov. Doktorska disertacija. Ljubljana, Biotehniška fakulteta Univerze v Ljubljani, Oddelek za agronomijo: 104 str.

Fabjan N., Rode J., Košir I. J., Wang Z., Zhang Z., Kreft I. 2003. Tartary buckwheat (Fagopyrum tataricum Gaertn.) as a source of dietary rutin and quercitin. Journal of Agricultural and Food Chemistry, 51: 6452–6455

Ferligoj A. 1997. Osnove statistike na prosojnicah. Ljubljana: Samozaložba Z. Batagelj. http://209.85.129.132/search?q=-cache:Img19icPFHgJ:www.fustudent.com/forum/index.php%3Fact%Dattach%26type%3Dpost%26id%3D735+v-zor%C4%8Dni+standardni+odklon&&cd=9&hl=sl&ct=clnk&gl=si (4.1.2010)

Ferligoj A., Lozar Manfreda K. 2009. Študijsko gradivo za statistiko. http://www.fdv.uni-lj.si/Index.asp (4.1.2010)

Gadžo D., Djikić M., Gavrić T., Kreft I. 2009. Comparison of phenolic composition of buckwheat sprouts and young plants. In: Developement and Utilization of Buckwheat Sprouts as medicinal natural products. Park C. H., Kreft I. (ur.). ISBS–Symposium of Buckwheat Sprouts, Sept. 7-9, Bongpyoung, Korea. Bongpyoung, IBRA: 60–65

Germ, M., Árvay, J., Vollmannová, A., Tóth, T., Golob, A., Luther, Z., Kreft, I. 2019. The temperature threshold for the transformation of rutin to quercitin in Tartary buckwheat dough. Food chemistry. [Print ed.]. 2019, 283, 28-31. DOI: 10.1016/j.foodchem.2019.01.038.

Ghimeray A. K., Sharma P., Briatia X. 2009. Phenolic content and free radical scavenging activity of seed, seedling and sprout of buckwheat. V: Development and Utilization of Buckwheat Sprouts as medicinal natural products. Park C. H., Kreft I. (ur.). ISBS – International Symposium of Buckwheat Sprouts, Sept. 7-9, Bongpyoung, Koreja. Bongpyoung, IBRA: 41–45

Hung P. V., Morita N. 2008. Distribution of phenolic compounds in the graded flours milled from whole buckwheat grains and their antioxidant capacities. Food Chemistry, 109: 325–331

Jiang P., Burczynski F., Campbell C., Pierce G., Austria J. 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 Research International, 40: 356–364

Kreft I. 1995. Ajda. Ljubljana: Kmečki glas: 112 str.

Kreft S., Knapp M., Kreft I. 1999. Extraction of rutin from buckwheat (Fagopyrum esculentum Moench) seeds and determination by capillary electrophoresis. Journal of Agricultural and Food Chemistry, 47: 4649–4652

Kreft, I., 2013: Buckwheat research from genetics to nutrition. FAGOPYRUM (Ljubljana) 30: 3-7.

Kreft, I., Š. Mechora, M. Germ & V. Stibilj, 2013: Impact of selenium on mitochondrial activity in young Tartary buckwheat plants. Plant physiology and biochemistry (Amsterdam) 63: 196-199. https://doi.org/10.1016/j.plaphy.2012.11.027

Kreft, I., G. Wieslander & B. Vombergar, 2016b: Bioactive flavonoids in buckwheat grain and green parts. In: Zhou M. & I. Kreft (Eds.): Molecular breeding and nutritional aspects of buckwheat. Academic Press is an imprint of Elsevier (London), pp. 161-167.

Kreft, M., 2016: Buckwheat phenolic metabolites in health and disease. Nutrition Research Reviews (Cambridge) 29(1): 30-39. https://doi.org/10.1017/S0954422415000190
Lin R. 2004. The development and utilization of tartary buckwheat resources. V: Advances in Buckwheat Research. Proceedings of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 252–258

Liu B., Zhu Y. 2007. Extraction of flavonoids from flavonoid-rich parts in tartary buckwheat and identification of the main flavonoids. Journal of Food Engineering, 78: 584–587

Morishita T., Yamaguchi H. Y., Degi K. 2007. The contribution of polyphenols to antioxidative activity in common buckwheat and tartary buckwheat grain (Post harvest Physiology). Plant Production Science, 10: 99–104

Mukasa Y., Suzuki T., Honda Y. 2009. Suitability of rice-tartary buckwheat for crossbreeding and for utilization of rutin. Japan Agricultural Research Quaterly, 43: 199–206 http://www.jircas.affrc.go.jp (8.9.2009)

Oomah B., D., Mazza G. 1996. Flavonoids and antioxidant activities in buckwheat. Journal of Agricultural and Food Chemistry, 44: 1746–1750

Park B. J., Park J. I., Chang, K. J., Park, C. H. 2004. Comparison in rutin content in seed and plant of tartary buckwheat (Fagopyrum tataricum). V: Advances in Buckwheat Research. Proceedings of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 626–629

Paulíčková I., Vyžralová K., Holasová M., Fiedlerová V., Vavreinová S. 2004. Buckwheat as functional food. In: Advances in Buckwheat Research. Proceedings of the 9th International Symposium on Buckwheat. Praga, Avgust 18-22. Praga, IBRA: 587–592

Piao S. I., Li L. H. 2001. The actuality of produce and exploitation of Fagopyrum in China. V: Advances in Buckwheat Research II. Proceedings of the 8th International Symposium on Buckwheat, Chunchon, Koreja, Avgust 30 - September 2. Chunchon, IBRA: 571–576

Quettier-Deleu C., Gressier B., Vasseur J., Dine T., Brunet C., Luyckx M., Cazin M., Cazin J. C., Bailleul F., Trotin F. 2000. Phenolic compounds and antioxidative activities of buckwheat (Fagopyrum esculentum Moench) hulls and flour. Journal of Ethnopharmacology, 72: 35–42

Senşoy Í., Rosen R. T., Ho C. T., Karwe M. V. 2006. Effect of processing on buckwheat phenolics and antioxidant activity. Food Chemistry, 99: 388–393

Steadman K. J., Burgoon M. S., Lewis B. A., Edwardson S. E., Obendorf R. L. 2001b. Minerals, phytic acid, tannin and rutin in buckwheat seed milling fractions. Journal of the Science of Food and Agriculture, 81: 1094–1100

Suzuki T., Honda Y., Funatsuki W., Nakatsuka K. 2002. Purification and characterization of flavonol 3-glucosidase, and its activity during ripening in tartary buckwheat seeds. Plant Science, 163: 417–423

Suzuki T., Honda Y., Mukasa Y. 2004. Effect of lipase, lypoxigenase and peroxidase on quality deteriorations in buckwheat flour. V: Advances in buckwheat research. Proceedings of the 9th International Symposium on Buckwheat, Praga, Avgust 18-22. Praga, IBRA: 692–698

Suzuki T., Kim S. J., Yamauchi H., Takigawa S., Honda Y., Mukasa Y. 2005. Characterization of flavonoid 3-O- glucosyltransferase and its activity during cotyledon growth in buckwheat (Fagopyrum esculentum). Plant Science, 169: 943–948

Škrabanja V., Krefl I., Golob T., Modic M., Ikeda S., Ikeda K., Krefl S., Bonafaccia G., Knapp M., Kosmelj K. 2004. Nutrient content in buckwheat milling fractions. Cereal Chemistry, 81: 172–176

Vombergar, B., 2010: Rutin v frakcijah zrn navadne ajde (Fagopyrum esculentum Moench) in tatarske ajde (Fagopyrum tataricum Gaertn.). Biotehniška fakulteta. Oddelek za agronomijo. Univerza v Ljubljani. Ljubljana. (Doktorska disertacija, 147 str.).

Vombergar, B., Škrabanja, V., Luthar, Z., Germ, M. 2017. Izhodišča za raziskave učinkov flavonoidov, taninov in skupnih beljakovin v frakcijah zrn navadne ajde in tartarske ajde /Starting points for the study of the effects of flavonoids, tannins and crude proteins in grain fractions of common buckwheat and Tartary buckwheat. Folia biologica et geologica, 58/2; 101-146
Watanabe M., Ohshita H., Tsushida T. 1997. Antioxidant compounds from buckwheat (Fagopyrum esculentum Moench) hulls. Journal of Agricultural and Food Chemistry, 45: 1039–1044
Yasuda T. 2001. Development of tartary buckwheat noodles through research on rutin-degrading enzymes and its effect on blood fluidity. In: Advances in Buckwheat Research II. The proceeding of the 8th International Symposium on Buckwheat, Chunchon, Korea, August 30 - September 2. Chunchon, IBRA: 499–502
Yasuda T. 2007. Synthesis of new rutinoside by rutin–degrading enzymes from tartary buckwheat seeds and its inhibitory effects on tyrosinase activity. V. Proceedings of the 10th International Symposium on Buckwheat, Yangling, Shanxi, Kitajska, Avgust 14-18. Yangling, IBRA: 558–562
Zhang J., Wang J., Brodbelt J. 2005. Characterization of flavonoids by aluminium complexation and collisionally activated dissociation. Journal of Mass Spectrometry, 40: 350–363

ACKNOWLEDGEMENTS
This study was financed by the Slovenian Research Agency, through the applied project L4-9305, co-financed by the Ministry of Agriculture, Forestry and Food, Republic of Slovenia.

IZVLEČEK
Z vidika funkcijskega dodatka ter hranih in prehranske vrednosti so zanimive mlevske frakcije ajde z granulacijo nad 100 µm do vključno 1000 µm (teh je pri mletju okoli 30 %); nezanimive pa so frakcije finih belih mok z granulacijo pod 100 µm (pri mletju nastaja skoraj 50 % belih mok), saj so revne z beljakovinami, minerali in flavonoidi. Zbiranje in mešanje frakcij (z granulacijo nad 100 µm do vključno 1000 µm), predvsem pri tatarski ajdi, pomeni najboljše izbijo glede vsebnosti beljakovin, mineralov in flavonoidov.

Tatarska ajda ima bistveno višjo vsebnost flavonoidov kot navadna ajda (tudi več kot 100-krat več flavonoidov v moki). Najvišja vsebnost flavonoidov je v mlevskih frakcijah tatarske ajde T1 (z granulacijo nad 100 µm do vključno 1000 µm) in sicer 3,5–4,5 % flavonoidov v sušini.

Flavonoidi, se po mlevskih frakcijah (z različno granulacijo) različno razporejeni. Razporeditev med mlevskimi frakcijami ni enaka pri tatarski in navadsni ajdi.

Pri neposrednem stiku mlevskih frakcij tatarske in navadne ajde z vodo vsebnost flavonoidov v vseh mlevskih frakcijah naraste (tudi za 100 % in več) v prvih 5–30-ih minutah delovanja. Po eni uri začne koncentracija flavonoidov padati zaradi razpada flavonoidov, oksidacijsko redukcijskih procesov, encimatskih procesov in drugih biokemijskih reakcij. Koncentracija flavonoidov po 24-ih urah stika moke z vodo je vedno nižja v primerjavi z začetno vrednostjo flavonoidov v testu po 5-tih minutah stika z vodo.