Fagopyrum 38 (2): 43-53 (2021)

Research paper

Rutin and quercetin in common and Tartary buckwheat flour and dough

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DOI https://doi.org/10.3986/fag0022

Received: May 26, 2021; accepted June 15, 2021.
Keywords: buckwheat; Tartary buckwheat, HPLC; rutin; quercetin; flavonoids

ABSTRACT

The concentration of flavonoids rutin and quercetin in flours of common and Tartary buckwheat was investigated. In Tartary buckwheat, concentration of rutin is much higher compared to common buckwheat. In Tartary buckwheat it was measured 1.17 to 1.75% rutin in dry matter, while in common buckwheat it was only 0.003%. After direct contact of buckwheat flour with water, different biochemical activities in Tartary buckwheat developed with rutin. After the time (5 minutes or two hours), the concentration of rutin is in the flour-water mixtures much lowered, and quercetin appeared. However, after quick initial changes, some rutin remained in flour-water mixtures even after 24 hours. In any way, after 24 hours of direct contact of flour particles with water, the concentration of quercetin is higher than that of rutin. It is established that the concentration of rutin in flour-water mixtures is the result of two processes. One is the release of rutin from grain structures and its dissolving in water, and the second is the release of rutin degrading enzymes from grain structures and their activity in solution.

INTRODUCTION

Knowledge about the concentration of rutin and other phenolic substances in buckwheat is important for the use of buckwheat in healthy food products. About the rutin content in buckwheat are many publications, some of them are dating from the middle of the previous century (Couch et al., 1946), and some are dated from more than 25 years ago. Since 1990, about considerable amounts of rutin and other polyphenolic substances reported some Slovenian authors (Luthar, 1992a; Kreft and Luthar, 1993; Kreft et al., 1994), there are as well many other reports, especially since the year 2000 (Kim et al., 2001; Kreft et al., 2006, Kim et al., 2008; Bonafaccia et al., 2009; Stojilkovski et al., 2013).

Phenolic substances are important for plants, as well as in human nutrition. They protect against viruses, bacteria, and against herbivores; they are protecting plants from UV radiation. In plants, the concentration of phenolic substances depends on species, cultivar, growing conditions, climate (temperature, light, precipitation) and agrotechnical factors (Häkkinen et al., 1999).

Flavonoids (for example, rutin, kaempferol and quercetin) are secondary metabolites of plants that deserve considerable attention because of their potential antioxidative, antivirus, antiallergic and other health-protecting effects (Griffith et al., 1944; Arima et al., 2002; Kawa et al., 2003; Russo et al., 2004; Anthoni et al., 2008). They are used in medicine, pharmacy, cosmetics, and nutrition (Bian et al., 2004; Lee et al., 2005; Anthoni et al., 2008; Vogrinčič et al., 2010; Costantini et al., 2014; Merendino et al., 2014; Lukšič et al., 2016a,b).

Rutin ($C_{27}H_{30}O_{16}$) is a quercetin-3-rutinozide. It is a product, produced by higher plants, protecting them against UV radiation (Gaberščik et al., 2002; Rozema et al., 2002). It exists in many plants, but only a few of them are of importance in human nutrition. Environmental factors, like UV radiation, are important in triggering its synthesis in plants (Kreft et al., 2002; Regvar et al., 2012). Rutin and its aglycone quercetin have an antioxidative impact *in vitro* and *in vivo*. Rutin degrading enzymes degrade rutin to quercetin and rutinose.

RUTIN IN BUCKWHEAT

In buckwheat rutin is the main flavonoid. It is located in different plant parts. There are different concentrations of rutin among buckwheat species and cultivars (Table 1). Ohsawa and Tsutsumi (1995), Kitabayashi et al. (1995) and Ghimery et al. (2009) discussed these differences. The concentrations depend on buckwheat plant genotype, development phases, growing conditions, weather, and differences among the years of cultivation.

Rutin is located in different parts of the plants, including the grain. In dark buckwheat flours, there is more rutin than in the light ones. Experiments revealed that Tartary buckwheat has more rutin in all parts of the plants than in common buckwheat (Briggs et al., 2004). About the differences in buckwheat, content reported several authors (Fabjan et al., 2003; Park et al., 2004a,b; Suzuki et al., 2004; Asami et al., 2007; Fabjan, 2007; Brunori and Végvári, 2007; Ghimeray et al., 2009). Even in groats and flour of Tartary buckwheat, there is more rutin in Tartary buckwheat in comparison to common buckwheat (Steadman et al., 2001). The concentration of rutin in buckwheat milling fractions was studied by Kreft et al. (1999), Hung and Morita (2008).

Literature reports that Tartary buckwheat contains from 30 to 150-times higher concentration of rutin than common buckwheat (Yasuda et al., 1994; Suzuki et al., 2002, Vombergar, 2010 and 2020), and that it has strong glucosidase activity because of the rutin degrading enzyme (Suzuki et al., 2002). It is supposed that rutin and the enzyme protect buckwheat grain from UV radiation during the maturation and some other activities (Suzuki et al., 2005).

Kreft et al. (2006) reported on rutin content in the grain of common buckwheat ´darina´, ´darja´ and ´siva II´. They find that rutin content in hydrothermally treated buckwheat (porridge) is significantly lower than in raw buckwheat. In addition, light buckwheat flour from the inside of the grains (endosperm) has a lower rutin content than darker flour from embryo and the outer layers of the grains.

Yasuda (2001) reported that buckwheat grain contains a large amount of rutin and enzymes that break down rutin. He noted that rutin is rapidly broken down into quercetin when water is added to flour. Many buckwheat dishes are prepared by mixing buckwheat flour and water. The dough, which is usually used for bread, pastries, or pasta, can rest for a specific time to develop the appropriate texture and technological properties. Several authors have reported the content of rutin in bread and pasta (Vogrinčič et al., 2010 and 2013; Costantini et al., 2014; Merendino et al., 2014). The use of Tartary buckwheat flour as a source of rutin is limited due to the enzymatic degradation of rutin in the dough preparation pro-

Table 1: *Rutin and quercetin content in common buckwheat flour and Tartary buckwheat flour*

Source	Sample	Rutin content	Quercetin content	References
Common buckwheat	Fine flour	0.155 g/kg DM	0.002 g/kg SS	Steadman et al. (2001)
Common buckwheat ´siva´	Light flour Dark flour	19 mg/kg DM 168 mg/kg DM		Kreft et al. (1999)
Common buckwheat	Flour	380–1010 mg/kg DM		Qian et al. (1999)
Common buckwheat	Flour	98 mg/kg		Quettier-Deleu et al. (2000)
Common buckwheat ´siva´, ´darja´	Flour	305–322 mg/kg DM	0	Fabjan (2007)
Common buckwheat	Flour	10–20 mg/100 g	cca. 1 mg/100 g	Asami et al. 2007
Common buckwheat	Light flour	19–168 mg/kg DM		Škrabanja et al. (2004)
Common buckwheat	Light flour	112.8 mg/kg DM		Kreft et al. (2006)
Common buckwheat	Coarse dark flour	57–77 mg/kg DM		Škrabanja et al. (2004)
Common buckwheat	Dark flour	218 mg/kg		Kreft et al. (2006)
Tartary buckwheat Lux01	Flour	6315 mg/kg DM	0	Fabjan (2007)
Tartary buckwheat Lux05	Flour	5049 mg/kg DM	0	Fabjan (2007)
Tartary buckwheat	Flour	30000 mg/kg		Mukasa et al. (2009)
Tartary buckwheat	Flour	1200 mg/100 g	cca. 1 mg/100 g	Asami et al. (2007)
Tartary buckwheat	Flour	20421 mg/kg DM		Soon-Mi et al. (2006)
Tartary buckwheat	Flour and water mixture (less than 100 min)	5000 mg/kg		Mukasa et al. (2009)
Tartary buckwheat (Luxemburg)	Bread	traces	4.99 mg/g	Germ et al. (2009)

cess, which also results in a bitter taste (Li et al., 2008). To determine the potential inactivation of enzymes that degrade rutin and cause a decrease in rutin content in products and discoloration during dough preparation, various authors studied different pre-treatment procedures of buckwheat (heating, steaming, cooking, extrusion). When boiling, cooking and extruding, most of the rutine can be retained, and the bitter taste does not appeare. The effect of fermentation on rutin and other polyphenols, enzyme activity, linkages to pH, and other factors was studied by Han et al. (2002) and Krahl et al. (2008). Research is also on the interactions between proteins and flavonoids (Arts et al., 2002).

MATERIAL AND METHODS

Material

Two buckwheat samples were investigated, common buckwheat (*Fagopyrum esculentum* Moench) – cv. ´siva´ from Slovenia (sample S), and a sample of Tartary buckwheat (*F. tataricum* Gaertn.) from Germany, originated from Luxemburg (sample T). Common buckwheat was obtained as grain, and Tartary buckwheat as a flour, after milling in Slovenia, 42% of flour gain from grain (sample T).

For the determination of rutin and quercetin, common husked buckwheat grain were milled on a Udy-Tecator Mill (Landskrona, Sweden) with a sieve with openings 0.7 mm, to obtain whole grain flour. For the determination of rutin and quercetin in Tartary buckwheat flour it was used the flour obtained.

Dough (flour-water mixture) was made by mixing 5 g of flour with 8 mL of distilled water, at the temperature 20°C. Duration of mixing was 20 seconds. Before the analyses dough was waiting covered at 20 ± 1°C for given time. After the given time, samples were frozen and freeze-dried. All analyses were performed in three independent samples.

HPLC analyses

a) Common buckwheat flour and dough were analysed at Biotechnical Faculty, University of Ljubljana, according the method described by Kreft, Fabjan in Yasumoto (2006).

b) Tartary buckwheat flour and dough were analysed at the Department of Chemistry, Slovak Agricultural University in Nitra, Slovakia, as described by Vombergar (2010).

RESULTS

a) Rutin and quercetin in common buckwheat flour and dough (sample S)

Common buckwheat flour contained 25.8 ± 1.4 µg rutin/g DM (dry matter) of sample; there were detected no traces of quercetin.

The highest concentration of rutin was in the dough 0.5 h respectively one hour after the beginning of contact of flour with water. After two hours of dough resting, it contained only about 3.8 µg/g rutin (in DM). Before the mixing of flour with water, it was no quercetin established in common buckwheat flour (Table 2 and Fig. 1). Quercetin appeared in the flour-water mixture after one hour, and the maximal value about 2.5 µg quercetin/g DM was reached after two hours from the beginning of flour-water contact. It is supposed that quercetin is the result of the decomposition of rutin. After 24 hours of dough resting, there were only traces of rutin (0.54 µg rutin/g DM), but appeared 2.3 µg/g DM quercetin (Table 2, Fig. 1).

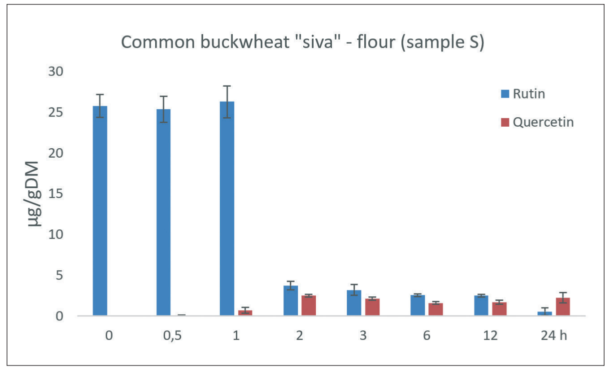

Figure 1: *Rutin and quercetin extracted from common buckwheat flour and from flour dough in the 24- hour period of dough resting (sample S)*

b) Rutin and quercetin in Tartary buckwheat flour and dough (sample T)

Tartary buckwheat flour (sample T) contained 11.67 ± 0.09 mg rutin/g DM, in the flour it was as well 0.63 ± 0.03 mg quercetin/g DM.

Concentration of rutin dropped down already after 5 min of the contact with water (to 0.79 ± 0.01 mg/g DM), after 24 hours no rutin was detected in the dough of Tartary buckwheat flour. In the dough of Tartary buckwheat flour it appeared after 5 min of flour-water contact 5.65 ± 0.01 mg quercetin/g DM. Quercetin is supposed to be

Table 2: *Rutin and quercetin concentrations in common buckwheat flour and in buckwheat dough (sample S) during the dough resting time*

Sample S (common buckwheat ´siva´)	Dough			
Time of contact of flour and water until measurement (h)	Rutin (µg/g DM)	SD	Quercetin (µg/g DM)	SD
0	25.8	1.40	UDL	-
0.5	25.39	1.61	0.10	0.01
1	26.32	1.96	0.71	0.36
2	3.75	0.53	2.50	0.18
3	3.21	0.68	2.14	0.17
6	2.56	0.18	1.61	0.18
12	2.50	0.19	1.71	0.25
24	0.54	0.46	2.25	0.61

n = 3
S - common buckwheat; flour, dough
UDL - under detection limit
SD - standard deviation
DM - dry matter

Table 3: *Rutin and quercetin concentrations in Tartary buckwheat flour (sample T) during the 24- hour period of dough resting*

Tartary buckwheat (sample T)	Dough			
Time of contact of flour and water until measurement (h)	Rutin (mg/g DM)	SD	Quercetin (mg/g DM)	SD
0	11.67	0.09	0.63	0.03
0.08	0.79	0.01	5.65	0.01
0.5	0.63	0.05	5.68	0.04
1	UDL	-	5.66	0.03
24	UDL	-	5.21	0.01

n = 3
T - Tartary buckwheat from Luxembourg (flour, dough)
UDL - under detection limit
SD - standard deviation
DM - dry mass

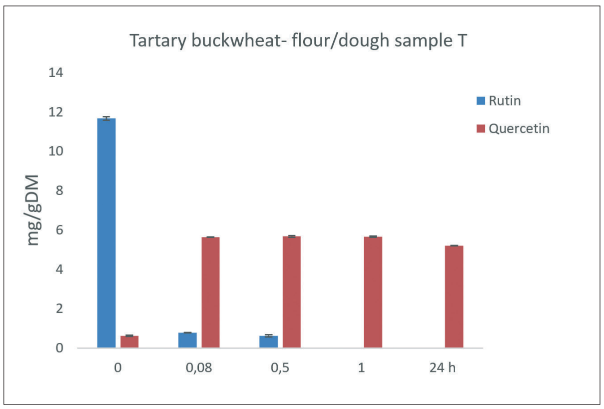

Figure 2: *Rutin and quercetin extracted from Tartary buckwheat flour and buckwheat flour dough in the 24-hour period of dough resting (sample T)*

the result of decomposition of rutin in the dough. After 24 hours of dough resting, the concentration of rutin is under the limit of detection, but there appeared about 5 mg quercetin/g DM (Table 3, Fig. 2).

DISCUSSION

It is known that beside the main flavonoid rutin, in Tartary buckwheat grain is as well some quercetin and quercitrin, rutin is responsible for about 85–90 % of antioxidative activity (Morishita et al., 2007; Liu and Zhu, 2007). Recent results show that in investigated sample of Tartary buckwheat rutin is important part of flavonoid content (T: flour 1.17 % rutin/DM). Previous investigations showed results in the similar range 0.24–4.47 % of flavonoids (Vombergar, 2010; Vombergar and Luthar, 2018; Vombergar et al., 2018; Vombergar, 2020). Similar results about higher content of flavonoids (mainly rutin) in Tartary buckwheat were reported by Fabjan et al. (2003), Briggs et al. (2004), Asami et al. (2007), Fabjan (2007), Jiang et al. (2007), Yu and Li (2008) and other. In the present investigation, it was established that our sample of Tartary buckwheat flour contained 400 times higher concentration of rutin than common buckwheat flour sample (Table 4).

Different methods of milling, use of different mills, obtaining of fraction with different granulation may have

Table 4: *Rutin and quercetin content in common buckwheat (sample S) and Tartary buckwheat (sample T3)*

Sample of flour	Rutin %/DM	Quercetin %/DM
Common buckwheat (S)	0.0026	UDL
Tartary buckwheat (T)	1.1670	0.063

UDL – under detection limit

impact on amount and speed of extraction of phenolic substances from milling fractions. Size of flour particles is very important for flour properties. Smaller particles have bigger contact surface with water, so the action of enzymes may be different. Impact of enzymes on small flour particles can be bigger. Phenolic substances are part of several grain and cell components. Their extraction could be thus different.

In previous research, investigated the common and Tartary buckwheat samples on the content of total flavonoids, we established similar trends after the contact of flour particles with water (Vombergar, 2010; Vombergar et al., 2018). Flavonoids concentration raised in milling fractions after 5 min of contact with water (in comparison to concentration in flour), up to 2 times or more, but later the concentration of total flavonoids was lower, especially after 24 hours of the flour-water contact it was lower.

Investigation established that the concentration of rutin in flour-water mixtures the result of two processes. One is extraction of rutin from grain structures and its dissolving in water, and the second is the relaxation of rutin degrading enzymes from grain structures and their activity in solution. However, the details of these processes are not yet known, it is a possibility of further investigation.

Very interesting is, that some rutin remains in the dough even after 24 hours of flour-water contact. We do not know, if this is due to the deactivation or decomposition of enzymes, or the remaining rutin is available for the extraction, but not available for the transformation by enzymes.

CONCLUSION

In Tartary buckwheat, we determined a much higher concentration of rutin in comparison to common buckwheat. In Tartary buckwheat, we determined from 1.17 to 1.75% rutin in dry matter, while it was in common buckwheat only 0.003%. After direct contact of buckwheat flour with water, different biochemical activities in Tartary buckwheat occur. After the time (5 minutes or two hours), the concentration of rutin is in the flour-water mixtures much lowered, and quercetin appeared. However, after quick initial changes, some rutin remained in flour-water mixtures even after 24 hours. In any way, after 24 hours of direct contact of flour particles with water, the concentration of quercetin is higher than that of rutin.

Investigation established that the concentration of rutin in flour-water mixtures is the result of two processes. One is extraction of rutin from grain structures and its dissolving in water, and the second is the relaxation of rutin degrading enzymes from grain structures and their activity in solution.

ACKNOWLEDGMENTS

This publication was supported by the Slovenian Research Agency, programs P1-0212 and P3-0395, and project L4-9305, co-financed by the Ministry of Agriculture, Forestry and Food, Republic of Slovenia. The final preparation of this publication was supported by the Operational program Integrated Infrastructure within the project: Demand-driven research for the sustainable and innovative food, Drive4SIFood 313011V336 (50%), cofinanced by the European Regional Development Fund, and Slovenian programs and project (50%). Author is thankful to Prof. Ivan Kreft (Nutrition Institute, Ljubljana, Slovenia), Prof. Alena Vollmannová (Department of Chemistry, Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra, Slovakia), to Dr. Maja Vogrinčič and Prof. Mateja Germ (Biotechnical Faculty, University of Ljubljana) for their advice and cooperation.

REFERENCES

Anthoni J., Lionneton F., Wieruszeski J. M., Magdalou J., Engasser J. M., Chebil L., Humeau C., Ghoul M. 2008. Investigation of enzymatic oligomerization of rutin. Rasayan Journal of Chemistry. 4, 718–731.

Arima, H., Ashid H., Danno G. 2002. Rutin – enhanced antibacterial activities of flavonoids against Bacillus cereus and Salmonella enteritidis. Bioscience, Biotechnology and Biochemistry. 66, 1009–1014. http://dx.doi.org/10.1271/bbb.66.1009

Arts M. J. T. J., Haenen G. R. M. M., Wilms L. C., Batstra S. A. J. N., Heijnen C. G. M., Voss H. P., Bast A. 2002. Interactions between flavonoids and proteins: effect on the total antioxidant capacity. Journal of Agricultural and Food Chemistry. 50, 1184–1187. https://doi.org/10.1021/jf010855a

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.

Bian J., Shan, F., Tian Z., Xu G., Lin R., Chunsheng X., Yali D., Mingjie J. 2004. Study on new health foods of Tartary buckwheat. Advances in Buckwheat Research. 714–718.

Bonafaccia G., Maccati F., Galli V. 2009. Dietary fiber and phenolic compounds in common and tatratary buckwheat. In: Park C. H., Kreft I. Developement and Utilization of Buckwheat as medicinal natural products. ISBS–International Symposium of Buckwheat Sprouts. 16–19.

Briggs C. J., Campbell C., Pierce G. Jiang P. 2004. Bioflavonoid analysis and antioxidant properties of tartary buckwheat accessions. Advances in Buckwheat Research: Proceedings of the 9th International Symposium on Buckwheat. 593–597.

Brunori A., Végvári G. 2007. Rutin content of the grain of buckwheat (*Fagopyrum esculentum* Moench and *Fagopyrum tataricum* Gaertn.) varieties grown in southern Italy. Acta Agronomica Hungarica. 55, 265–272. https://doi.org/10.1556/AAgr.55.2007.3.1

Costantini L., Lukšič L., Molinari R., Kreft I., Bonafaccia G, Manzi L., Merendino N. 2014. Development of gluten-free bread using Tartary buckwheat and chia flour rich in flavonoids and omega-3 fatty acids as ingredients. Food Chemistry. 165, 232-240. https://doi.org/10.1016/j.foodchem.2014.05.095

Couch J. F., Naghski J., Krewson C. F. 1946. Buckwheat as a source of rutin. Science. 103, 197–198. https://doi.org/10.1126/science.103.2668.197

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 quercitrin. Journal of Agriculture and Food Chemistry. 51, 6452–6455. https://doi.org/10.1021/jf034543e

Fabjan N., 2007. Zel in zrnje tatarske ajde kot vir flavonoidov. Biotehniška fakulteta. Oddelek za agronomijo. Univerza v Ljubljani. Doktorska disertacija. 104.

Gaberščik A., Vončina M., Trošt T., Germ M., Bjőrn L. O. 2002. Growth and production of buckwheat (*Fagopyrum esculentum*) treated with reduced, ambient and enhanced UV-B radiation. Journal of Photochemistry and Photobiology B: Biology. 66, 30–36. https://doi.org/10.1016/S1011-1344(01)00272-X

Germ M., Vollmannová A., Timoracka M., Melichacova S., Stibilj V., Vogrinčič M., Kreft I. 2009: Antioxidative substances of Tartary buckwheat sprouts and impact of Se and Zn on the sprout development. Park C. H., Kreft I. Developement and Utilization of Buckwheat Sprouts as medicinal natural products. ISBS – International Symposium of Buckwheat Sprouts. 46–53.

Ghimeray A. K., Sharma P., Briatia X. 2009. Phenolic content and free radical scavenging activity of seed, seedling and sprout of buckwheat. Park C. H., Kreft I. Developement and Utilization of Buckwheat Sprouts as medicinal natural products. ISBS – International Symposium of Buckwheat Sprouts. 41–45.

Griffith J. Q., Couch J. F., Lindauer A. 1944. Effect of rutin on increased capillary ̦fragility in man. Proceedings of Society for Experimental Biology and Medicine. 55, 228–229.

Häkkinen S. H., Kärenlampi S. O., Heinonen I. M., Mykkänen H. M., Törrönen A. R. 1999. Content of the flavonols quercetin, myricetin and kaempferol in 25 edible berries. Journal of Agricultural and Food Chemistry. 47, 2274–2279. https://doi.org/10.1021/jf9811065

Han M., Chang Y. I., Lee S. J., Park J. M., Kwon B. K. 2005. Stability of rutin by pH and enzymes during fermentation of buckwheat gochujang. IFT Annual Meeting.

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. https://doi.org/10.1016/j.foodchem.2007.12.060

Ikeda K., Ikeda S., Kreft I., Lin R. 2012. Utilization of Tartary buckwheat. Fagopyrum. 29, 27-30.

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. https://doi.org/10.1016/j.foodres.2006.10.009

Kawa J. M., Taylor C. G., Przybylski R. 2003. Buckwheat concentrate reduces serum glucose in streptozotocin-diabetic rats. Journal of Agricultural and Food Chemistry. 51, 7287-7291. https://doi10.1021/jf0302153

Kim Y. S., Kim J. G. 2001. Studies on the rutin content and fatty acid composition in buckwheat sprouts. Advances in Buckwheat Research II: Proceedings of the 8th International Symposium on Buckwheat. 561–563.

Kim S. J., Zaidul I. S. M., Suzuki T., Mukasa Y., Hashimoto N., Takigawa S., Noda T., Matsuura-Endo C., Yamauchi H. 2008. Comparison of phenolic compositions between common and Tartary buckwheat (*Fagopyrum*) sprouts. Food Chemistry.110, 814–820. https://doi.org/10.1016/j.foodchem.2008.02.050

Kitabayashi H., Ujihara A., Hirose T., Minami M. 1995. On the genotypic differences for rutin content in tartary buckwheat *Fagopyrum tataricum* Gaertn. Breeding Science. 45, 189–194. https://doi.org/10.1270/jsbbs1951.45.189

Krahl M., Back W., Zaznkow M., Kreisz S. 2008. Determination of optimised malting conditions for the enrichment of rutin, vitexin and orientin in common buckwheat (*Fagopyrum eculentum* Moench). Journal of the Institute of Brewing. 114, 294–299. https://doi.org/10.1002/j.2050-0416.2008.tb00772.x

Kreft I., Luthar Z. 1993. Sekundarni metaboliti ječmena, ajde in šentjanževke kot možne protivirusne učinkovine. Zbornik Biotehniške fakultete Univerze v Ljubljani – Agronomija. 61, 29–32.

Kreft I. 1994. Traditional buckwheat food in Europe. Bulletin of the Research Institute for Food Science. 57, 1–8.

Kreft I., Bonafaccia G., Žigo A. 1994. Secondary metabolites of buckwheat and their importance in human nutrition. Prehrambeno-tehnološka i biotehnološka revija. 32, 195–197.

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. https://doi.org/10.1021/jf990186p

Kreft I. 2001. Buckwheat research, past, present and future perspectives – 20 years of internationationality coordinated research. Advances in Buckwheat Research I: Proceedings of the 8th International Symposium on Buckwheat. 361–366.

Kreft I., Škrabanja V. 2002. Nutritional properties of starch in buckwheat noodles. Journal of Nutritional Science and Vitaminology. 48, 47–50.

Kreft S., Štrukelj B., Gaberščik A., Kreft I. 2002. Rutin in buckwheat herbs grown at different UV-B radiation levels: comparison of two UV spectrophotometric and an HPLC method. Journal of Experimental Botany. 53, 1801–1804. https://doi.org/10.1093/jxb/erf032

Kreft I. 2003. *Buckwheat in Slovenia*. Kreft I., Chang J. K., Choi Y. S., Park C. H. Ethnobotany of Buckwheat. Jinsol Publishing Co. 91–115.

Kreft I., Fabjan N., Yasumoto K. 2006. Rutin content in buckwheat (*Fagopyrum eculentum* Moench) food materials and products. Food Chemistry. 98, 508–512. https://doi.org/10.1016/j.foodchem.2005.05.081 Kreft I. 2013. Buckwheat research from genetics to nutrition. Fagopyrum. 30, 3-7.

Kreft I., Vombergar B., Pongrac P., Park C. H., Ikeda K., Ikeda S., Vollmannová A., Dziedzic K., Wieslander G., Norbäck D., Škrabanja V., Pravst I., Golob A., Lukšič L., Bonafaccia G., Chrungoo N. K., Zhou M., Vogel-Mikuš K., Regvar M., Gaberščik A., Germ M. 2016. Coordinated buchwheat research: genetics, environment, structure and function. The 13th international symposium on buckwheat. 29-37.

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

Kreft M., 2016. Buckwheat phenolic metabolites in health and disease. Nutrition Research Reviews. 29, 30-39. https://doi.org/10.1017/S0954422415000190

Lee S. J., Kim S. J., Han M. S., Chang K. S. 2005. Changes of rutin in quercetin in commercial Gochujang prepared with buckwheat flour during fermentation. Journal of Korean Society of Food Science and Nutrition. 34, 509–512. https://doi.org/10.3746/jkfn.2005.34.4.509

Li D., Li X., Ding X., Park K. H. 2008. A process for preventing enzymatic degradation of rutin in tartary buckwheat (*Fagopyrum tataricum* Gaertn.) flour. The Food Science and Biotechnology.17, 118–122.

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. https://doi.org/10.1016/j.jfoodeng.2005.11.001

Lukšič L., Árvay J., Vollmannová A., Tóth T., Skrabanja V., Trček J., Germ M. Kreft I. 2016a. Hydrothermal treatment of Tartary buckwheat grain hinders the transformation of rutin to quercetin. Journal of Cereal Science. 72, 131-134. https://doi.org/10.1016/j.jcs.2016.10.009

Lukšič L., Bonafaccia G., Timoracká M., Vollmannová A., Trček J., Koželj N. T., Melini V., Acquistucci R., Germ M., Kreft I. 2016b. Rutin and quercetin transformation during preparation of buckwheat sourdough bread. Journal of cereal science. 69, 71-76. https://doi.org/10.1016/j.jcs.2016.02.011

Luthar Z. 1992. Polyphenol classification and tannin content of buckwheat seeds *(Fagopyrum esculentum* Moench). Fagopyrum.12, 36–42.

Merendino N., Molinari R., Costantini L., Mazzacuto A., Pucci A., Bonafaccia F., Esti M., Ceccantoni B., Papeschi C., Bonafaccia G. 2014. A new "functional" pasta containing Tartary buckwheat sprouts as an ingredient improves the oxidative status and normalizes some blood pressure parameters in spontaneously hypertensive rats. Food & Function. 5, 1017–1026. https://doi.org/10.1039/C3FO60683J

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. http://dx.doi.org/10.1626/pps.10.99

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://doi.org/10.6090/jarq.43.199

Ohsawa R., Tsutsumi T. 1995. Inter-varietal variations of rutin content in common buckwheat flour (*Fagopyrum esculentum* Moench). Euphytica. 86, 183–189.

Park B. J., Park C. H. 2004a. Cytotoxic activities of tartary buckwheat against human cancer cells. Advances in Buckwheat Research. Proceedings of the 9th International Symposium on Buckwheat. 665–668.

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

Pongrac P., Potisek M., Fraś A., Likar M., Budič B., Myszka K., Boros D., Nečemer M., Kelemen M., Vavpetič P., Pelicon P., Vogel-Mikuš K., Regvar M., Kreft I. 2016. Composition of mineral elements and bioactive compounds in Tartary buckwheat and wheat sprouts as affected by natural mineral-rich water. Journal of Cereal Science. 69, 9-16. https://doi.org/10.1016/j.jcs.2016.02.002

Ian J. Y., Mayer D., Kuhn M. 1999. Flavonoids in fine buckwheat (*Fagopyrum esculentum* Moench) flour and their free radical scavening activities. Deutsche Lebensmittel-Rundschau. 95, 343–349.

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 antioxidant activities of buckwheat (*Fagopyrum esculentum* Moench) hulls and flour. Journal of Ethnopharmacology. 72, 35–42. https://doi.org/10.1016/S0378-8741(00)00196-3

Regvar M., Bukovnik U., Likar M. Kreft I. 2012. UV-B radiation affects flavonoids and fungal colonisation in *Fagopyrum esculentum and F. tataricum*. Central European Journal of Biology. 7, 275-283. https://doi.org/10.2478/s11535-012-0017-4

Rozema J., Björn L. O., Bornman J. F. 2002. The role of UV–B radiation in aquatic and terrestrial ecosystems – an experimental and functional analysis of the evolution of UV–B compound. Journal of Photochemistry and Photobiology, B. Biology. 66, 2–12. https://doi.org/10.1016/S1011-1344(01)00269-X

Russo A., Acquaviva R., Campisi A., Sorrenti A., Di Giacomo C., Virgata G., Barcellona L., Vanella A. 2000. Bioflavonoids as antiradicals, antioxidants and DNA cleavage protectors. Cell Biology and Toxicology. 16, 91–98. https://doi.org/10.1023/A:1007685909018

Soon-Mi K., Park J. I., Park B. J., Chang K. J., Park C. H. 2006. Flavonoid content and antioxidant activity of tartary buckwheat. Proceedings of International forum on tartary industrial economy. 149–153.

Steadman K. J., Burgoon M. S., Lewis B. A., Edwardson S. E., Obendorf R. L. 2001. Minerals, phytic acid, tannin and rutin in buckwheat seed milling fractions. Journal of the Science of Food and Agriculture. 81, 1094–1100. https://doi.org/10.1002/jsfa.914

Stojilkovski K., Kočevar G. N., Kreft S., Kreft I. 2013. Fagopyrin and flavonoid contents in common, Tartary, and cymosum buckwheat. Journal of Food Composition and Analysis. 32, 126-130. https://doi.org/10.1016/j.jfca.2013.07.005

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. https://doi.org/10.1016/S0168-9452(02)00158-9

Suzuki T., Honda Y., Mukasa Y. 2004. Effect of lipase, lypoxigenase and peroxidase on quality deteriorations in buckwheat flour. Advances in buckwheat research: Proceedings of the 9th International Symposium on Buckwheat. 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. https://doi.org/10.1016/j.plantsci.2005.06.014

Škrabanja V., Kreft I., Golob T., Modic M., Ikeda S., Ikeda K., Kreft S., Bonafaccia G., Knapp M., Kosmelj K. 2004. Nutrient content in buckwheat milling fractions. Cereal Chemistry. 81, 172–176. https://doi.org/10.1094/CCHEM.2004.81.2.172

Vogrinčič M., Timoracka M., Melichacova S., Vollmannova A., Kreft I. 2010. Degradation of rutin and polyphenols during the preparation of Tartary buckwheat bread. Journal of Agricultural and Food Chemistry. 58, 4883-4887. http://dx.doi.org/10.1021/jf9045733

Vogrinčič M., Kreft I., Filipič M., Žegura B. 2013 Antigenotoxic effect of Tartary (*Fagopyrum tataricum*) and common (*Fagopyrum esculentum*) buckwheat flour. Journal of Medicinal Food. 16, 944-952. https://doi.org/10.1089/jmf.2012.0266

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. Doktorska disertacija. 147.

Vombergar B., Kreft I., Horvat M., Vorih S. 2018. Ajda = Buckwheat. Dopolnjena izdaja. Ljubljana: ČZD Kmečki glas.

Vombergar B., Luthar Z. 2018. Raziskave vsebnosti flavonoidov, taninov in skupnih beljakovin v frakcijah zrn navadne ajde (*Fagopyrum esculentum* Moench) in tatarske ajde (*Fagopyrum tataricum* Gaertn.). Folia biologica et geologica. 59, 101-158.

Vombergar B., Škrabanja V., Germ M., 2020. Flavonoid concentration in milling fractions of Tartary and common buckwheat. Fagopyrum. 37, 11-21.

Vombergar, B., 2020. Rutin in kvercetin v moki iz navadne in tatarske ajde. Folia biologica et geologica. 61, 101-158.

Wieslander G., Fabjan N., Vogrinčič M., Kreft I., Janson C., Spetz-Nyström U., Vombergar B., Tagesson C., Leanderson P., Norbäck D. 2011. Eating buckwheat cookies is associated with the reduction in serum levels of myeloperoxidase and cholesterol: a double blind crossover study in day-care centre staffs. Tohoku Journal of Experimental Medicine. 225, 123-130.

Wieslander G., Fabjan N., Vogrinčič M., Kreft I., Vombergar B., Norbäck D. 2012. Effects of common and Tartary buckwheat consumption on mucosal symptoms, headache and tiredness: A double-blind crossover intervention study. International Journal of Food, Agriculture & Environment – JFAE. 10, 107-110.

Yan C., Baili F., Yingang H., Jinfeng G., Xiaoli G. 2004. Analysis on the variation of rutin content in different buckwheat genotypes. Advances in Buckwheat Research: Proceedings of the 9th International Symposium on Buckwheat. 688–691.

Yang J. 2014. Application perspective of tartary buckwheat as sports supplements. Journal of Chemical and Pharmaceutical Research. 6, 1239-1241.

Yasuda T., Nakagawa H. 1994. Purification and characterization of rutin-degrading enzymes in tartary buckwheat seeds. Phytochemistry. 37, 133–136. https://doi.org/10.1016/0031-9422(94)85012-7

Yasuda T. 2001. Development of tartary buckwheat noodles through research on rutin- degrading enzymes and its effect on blood fluidity. Advances in Buckwheat Research II; The proceeding of the 8th International Symposium on Buckwheat. 499–502.

Yasuda T. 2007. Synthesis of new rutinoside by rutin–degrading enzymes from tartary buckwheat seeds and its inhibitory effects on tyrosinase activity. Proceedings of the 10th International Symposium on Buckwheat. 558–562.

Yu Z. Li X. 2007. Determination of rutin content on chinese buckwheat cultivars. Proceedings of the 10th International Symposium on Buckwheat. 465–468.

Zhou X., Hao T., Zhou Y., Tang W., Xiao Y., Meng X., Fang X. 2015. Relationships between antioxidant compounds and antioxidant activities of Tartary buckwheat during germination. Journal of Food Science and Technology. 52, 2458–2463. http://dx.doi.org/10.1007/s13197-014-1290-1

IZVLEČEK

Vsebnost rutina in kvercetina v moki in testu navadne in tatarske ajde

Izvedena je bila primerjava vsebnosti rutina in kvercetina v mokah navadne in tatarske ajde. Tatarska ajda ima bistveno višjo vsebnost rutina kot navadna ajda. Vsebnost rutina v tatarski ajdi je 1,17–1,75 % v suhi snovi, v navadni ajdi ´siva´ pa le 0,003 %. V tatarski ajdovi moki ugotavljamo torej okoli 400x več rutina kot v navadni ajdovi moki. Pri neposrednem stiku ajdove moke z vodo težko najdemo vzporednice med tatarsko in navadno ajdo ter dogajanji v povezavi z rutinom v testu. Koncentracija rutina v testu se po določenem času (različen čas pri navadni in tatarski ajdi – 5 minut do 2 uri) močno zniža, pojavi se kvercetin. Ugotavljamo, da kljub burni začetni reakciji razgradnje rutina v testih, rutin ne razpade popolnoma, ampak se ga minimalna količina ohrani v testu tudi po 24 urah. Vsebnost kvercetina v testu je po 24 urah višja kot vsebnost rutina. Dosedanje raziskovanje je pokazalo, da je vsebnost rutina v zmesi mlevske frakcije zrn ajde in vode rezultanta dveh procesov. Na eni strani je to izločanje rutina iz struktur zrna in njegovo raztapljanje v tekočini. Drugi proces je sproščanje encimov, ki razgrajujejo rutin.