AGRONOMSKI GLASNIK 4/2008.
ISSN 0002-1954

Scientific review
Pregledni znanstveni članak

ORGANICALLY GROWN BUCKWHEAT AS A HEALTHY FOOD AND A SOURCE OF NATURAL ANTIOXIDANTS

EKOLOŠKI UZGOJENA HELJDA – ZDRAVA HRANA I IZVOR PRIRODNIH ANTIOKSIDANATA

I. Kreft, Mateja Germ

ABSTRACT

Common buckwheat (*Fagopyrum esculentum*) and tartary buckwheat (*Fagopyrum tataricum)* are because of their phenolic substances content resistant to grazing by animals, pests, diseases, UV radiation and unfavourable soil conditions. Buckwheat is sensitive to application of mineral fertilizers, especially nitrogen fertilizers. Buckwheat is as a semi-wild plant suitable for growing without pesticides and artificial mineral fertilisation. All these make buckwheat suitable for production of organically grown foods.

Key words: buckwheat, health, antioxidants, bread, organic agriculture

SAŽETAK

Obična heljda (*Fagopyrum esculentum*) i tatarska heljda (*Fagopyrum tataricum)* su zbog sadržaja fenolnih supstanca otporne na napade štetnika i bolesti, te otporne na UV-B zrake i nepogodne uvjete zemljišta. Heljda se često ponaša kao divlja, nekultivirana biljka te je osjetljiva na upotrebu mineralnih gnojiva. Zbog nabrojanih osobina, heljda je pogodna biljka za upotrebu u organskoj poljoprivredi.

Ključne riječi: heljda, zdravlje, antioksidanti, kruh, organska poljoprivreda

INTRODUCTION

Buckwheat (*Fagopyrum esculentum* Moench) is a crop originating in the Southwest China. In Europe it has been grown since the beginning of the 15th century. Progress in buckwheat breeding was slow because of the complex genetic system, including self-incompatibility and floral dimorphism.

Talk given at the 2nd Mediterranean Conference on Organic Agriculture, Dubrovnik, 2-6 April, 2008

Buckwheat is in modern time mainly eaten because of its taste, for variety in the menu, for its tradition, and mostly combined with the knowledge about the importance of buckwheat food products for human health. These demands and reasons for consuming buckwheat may be met by buckwheat products of highest possible quality, with typical and clearly pronounced taste and containing of all nutrients, important for human health¸ and free from artificial chemicals.

Buckwheat may be an important alternative crop in agriculture and a raw material for interesting foods (Kreft, 1994). Renewed interest for buckwheat is based on nutritional composition and on the fact that buckwheat is feasible for natural, organic production.

SELENIUM AND OTHER TRACE ELEMENTS IN BUCKWHEAT

Buckwheat is very rich in trace elements (for example Zn, Cu, Mn and Se), however, it must be grown in unpolluted areas, to avoid accumulation of contaminating elements. Different milling fractions may contain different minerals and proteins, dark flours being generally richer than the light ones (Ikeda and Yamashita, 1994; Kreft et al., 1996). Light milling fractions have higher starch content.

In several regions in Asia and Europe there is a deficiency of Se in diets. But locally there may also be deleteriously high Se contents in food. Knowledge on the amount, appearance and availability of Se in food may be important.

In the grain crops previously studied (wheat, rice, soybean), an important amount of Se could be in proteins, as selenomethionine (Olson et al., 1970; Yasumoto et al., 1988; Sathe et al., 1992a; Sathe et al., 1992b; Wang et al., 1996).

The selenium in buckwheat samples was analysed by radiochemical neutron activation analysis (RNAA) at the Jožef Stefan Institute in Ljubljana by the method described earlier (Dermelj et al., 1991; Stibilj et al., 1994).

In different milling fractions of buckwheat (cv. Siva), grown in the Domžale region, Slovenia, the Se content of about 10 ng/g (dry matter basis) was found in light buckwheat flour fractions, and in dark buckwheat flours milled from the same seed sample, up to 35 ng/g (d.m.b.). In germs of

buckwheat, grown in Slovenia there was up to 120 ng/g of Se and in groats of some buckwheat samples from China there was up to about 340 ng/g of Se (Modic et al., unpublished results). Buckwheat bread may thus be an important source of dietary selenium.

RUTIN AND OTHER SECONDARY METABOLITES

Buckwheat contains a significant amount of rutin (quercetin-3-rutinosid) and other polyphenols (Luthar, 1992). rutin in buckwheat is listed among the most important characteristics from the viewpoint of nutrition (Michalova, 1998). Rutin, quercetin and some other polyphenols may be, in moderate amounts, potent anticarcinogens in the colon and other organs. The anticarcinogenic and antimutagenic potentials may be related to their antioxidative property, which is important in the protection against cellular oxidative damage. Phenolic compounds may lower the blood sugar and lipid levels and contribute to the hypocholesterolaemic effect (Thompson, 1993). Analysing gene-bank buckwheat samples from different countries using the vanillin-HCl method, we found from 0.5 to 4.5% of polyphenols in buckwheat seeds and from 0.06 to 0.86% in respective flours. Buckwheat milling fractions with higher protein content may also be richer in functionally important polyphenols (Luthar, 1992; Kreft et al., 1994).

Rutin is mainly located in flowers and in green parts of buckwheat plant. In seeds there is less rutin than in leaves, but there could be some rutin as well in buckwheat flours, more in the dark than in the light ones. Buckwheat samples may differ according to rutin content in regard both to the genotype and to growing conditions. Generally, tartary buckwheat contains more rutin than common buckwheat. In analysing rutin content and in preparing food, nutraceutic and pharmaceutic preparations, it should be taken into account, that rutin could be, because of the presence of rutin degrading enzymes, relatively quickly degraded in common buckwheat (Eskin et al., 1998; Kreft et al., 2006). At the temperature over 80 ^{0}C rutin-degraded enzymes could be inactivated. So scalding of buckwheat flour prior to bread making; or heating of kasha (groats, dehusked buckwheat grains) prior to further application, could have a positive effect on the rutin content in buckwheat food. On the other hand, slow drying of buckwheat leaves, noodle making procedure or some biotechnologies

(production of buckwheat beer or buckwheat vinegar) may cause a significant degradation of rutin (Kreft et al., 2006).

Quercetin is normally not possible to find in higher amount in ripe buckwheat plants, but it may appear as a product of degradation of rutin in harvested plant parts.

Fagopyrin is a photo-sensitive substance of buckwheat plant, belonging to naphthodianthrones and structurally related to hypericin; it is not yet known, if fagopyrin have similar antiviral or other effects as hypericin. Fagopyrin was found in flowering buckwheat plants, so exposure to sunlight is not advisable for people after the consumption of meals containing plenty of green parts and/or flowers of buckwheat. It is not yet known if it is some fagopyrin as well in buckwheat seeds. In buckwheat, some anthranoides could be found as well, in the concentrations which could cause very small laxative effects (Hagels, 2007). Hagels (2007) published many interesting new data on rutin and other secondary metabolytes in buckwheat.

BUCKWHEAT PROTEINS

In buckwheat embryo and cotyledons, there are many proteins of high nutritional value, as well as some oils and fibers. Buckwheat is nutritionally interesting because of its balanced amino acid composition (high and balanced content of amino acids lysine, methionine, cysteine and other essential amino acids), and the high biological value of its proteins (Eggum, 1980; Eggum et al., 1981). The biological value (BV) of buckwheat seed proteins is 93, in comparison to egg proteins having BV 100, pork 84, soybean meal 68 and wheat 63. Buckwheat has a very low of prolamins content (Javornik and Kreft, 1984) and, based on chemical and immunological studies, it may be a valuable source of dietary protein for gluten-sensitive individuals (Skerritt, 1986).

STARCH AND DIETARY FIBRE

Cells of buckwheat endosperm contain many starch grains, which are in buckwheat very small, in comparison to wheat, rye or barley. In wheat, there is a great variation in the size of individual starch grains. On the contrary, buckwheat starch grains are much smaller and of even size. So, some large

starch grains present in buckwheat flour indicate that there is probably some wheat flour in buckwheat flour. Such identification is very important in the control of purity of buckwheat flour, when it is used for gluten sensitive (celiac disease) patients.

Carbohydrates are important in the human diet. Resistant or slowly digestible carbohydrates help to flatten the glycaemic response curve. A comparison of glycaemic response to spaghetti, rice, bread and potatoes shows a connection between starch alpha-amylase susceptibility and insulin responses (Guezennec et al., 1993). Some other health benefits of resistant starch exist. Its fermentation in the large intestine may be an important protective factor against the development of colon cancer due to a higher proportion of butyrate in the short chain fatty acids produced by the microflora (Bornet, 1993; Annison and Topping, 1994, Cassidy et al., 1994). Resistant starch may also affect factors such as plasma total cholesterol and triacylglycerol in a way similar to that of soluble non-starch polysaccharides.

In buckwheat groats, it is less digestible starch (in comparison to white wheat bread). The slowly digested, or non-digested starch of buckwheat groats exhibits effects similar to those of dietary fibre. It could be nutritionally important to diabetics, as it helps to flatten the glycaemic response curve. A slow release of glucose from starch could prolong endurance during physical activities and the duration of satiety is prolonged as well (Škrabanja and Kreft, 1998).

As wheat starch is generally rapidly digestible, combination with buckwheat gives the food some resistant starch, which is important for prevention of colon cancer and lowering the glycaemic index.

Bonafaccia and Kreft (1994) found from 3.4% to 5.2 % of total dietary fibre in buckwheat samples and products. About 20% to 30% of that was soluble fibre. These are very good values in comparison to other cereals and cereal foods. Buckwheat may have, because of its fibres content, an important role in the prevention and treatment of both hypertension and hypercholesterolemia, as it was found by some studies, performed in China (He et al., 1995).

Buckwheat embryo contains soluble carbohydrates, including fagopyritols (Obendorf, 1998). Incorporation of buckwheat bran milling fraction into foods could provide a natural healthy food which may help in combating the non-insulin dependent diabetes mellitus (Steadman and Obendorf, 1998).

TECHNOLOGICAL CHARACTERISTICS

Buckwheat has no gluten, so special technology should be applied for making products from pure buckwheat flour, or it could be used in blends with wheat flour. Besides proteins (mainly those soluble in water and salt solution), starch may be important as well for the textural characteristics of buckwheat products (Ikeda et al., 1997). Concerning buckwheat foods, characterisation of their components may lead to further developments in this research field and technology. Clarifying the molecular basis for the determinants of the palatability and acceptability of buckwheat foods is a subject of great interest (Ikeda et al., 1998).

Very popular, especially in Slovenia, Croatia, Poland, Ukraine and Russia, are groats, obtained by dehusking of hydrothermaely treated (pre-cooked) buckwheat grains. Technology of some buckwheat products could be based on buckwheat groats obtained by traditional technology, namely dehusking buckwheat grains after the hydrothermal pre-treatment (soaking or cooking in boiling water), to obtain hard buckwheat groats (or kasha), which are then further cooked and prepared for consumption. There is also a need for a dehusking device, suitable for dehusking untreated, raw buckwheat grains. The inner part of hydrothermally untreated grain is much more fragile than the groats from pre-treated grains and dehusking device should be adapted to this feature. One of the important demands to be solved before delivering the buckwheat into the de-husking process is the suitable separation of the grain according to the size, by sieves with triangulary shaped holes. The system of sieves separates different buckwheat grains according to their size. Different size fractions are dehusked by different dehuskers. After the dehusking process, the mixture of dehusked buckwheat, husks and redundant products such as broken groats, flour or whole grains are collected for further separation. Groats and other final products have to be divided by the system of sieves, and the non-husked buckwheat could be returned to the process.

In Slovenia, besides the most frequent blend of 30% of buckwheat flour and 70% of wheat flour for bread, sometimes (especially in households) mixtures of 50:50 are also used, and it is even feasible to make leavened bread from a blend of up to 70% of buckwheat flour and 30% of wheat flour. However this bread is very heavy and moist, but with a special typical taste. In Slovenia, the popular method is to admix the boiling water to buckwheat flour (scalding the flour), to wait for a while for the temperature of the mixture to decrease to about 30-40 ^{0}C, and then to add the required amount of wheat flour, yeast and salt.

Buckwheat bread is popular for consumption in Slovenia. In combination with high-quality wheat flour (for example the Croatian wheat cv. Divana) it is possible to produce a high quality wheat-buckwheat bread (Kreft et al., 1998).

Organically grown buckwheat products have become very popular in the countries of Central Europe in the last few years.

ACKNOWLEDGEMENT

This research is a part of the projects financed by the Slovenian Research Agency (ARRS), Ljubljana: “The influence of UV-B radiation on antioxidant content and distribution in cultivated plants” (J7-9805-0106-06, and J4-9673-0481-06).

REFERENCES

1. Annison G., Topping D.L. 1994. Nutritional role of resistant starch: Chemical structure vs. physiological function. Ann. Rev. Nutrition 14:297-320.
2. Bonafaccia G., Kreft I. 1994. Technological and qualitative characteristics of food products made with buckwheat. Fagopyrum 14:35-42.
3. Bonafaccia G., Marocchini M., Kreft I. 2003. Composition and technological properties of the flour and bran from common and tartary buckwheat. Food Chem., 80:9-15.
4. Bornet F. 1993. Technological treatments of cereals. Repercussions on the physiological properties of starch. Carbohydrate Polymers 21:195-203.
5. Cassidy A., Bingham S.A., Cummings J.H. 1994. Starch intake and colorectal cancer risk: an international comparison. British J. Nutrition 69:937-942.

6. Dermelj M., Stibilj V., Stekar J., Byrne A.R. 1991. Simultaneous determination of iodine and selenium in biological samples by radiochemical neutron activation analysis. Frasenius Journal of Analytical Chemistry, 341:258-261.
7. Eggum B.O. 1980. The protein quality of buckwheat in comparison with other protein sources of plant or animal origin. In: Kreft, I. ed./Javornik, B. ed./Dolinšek, B. ed. Symposium on Buckwheat, Ljubljana, 1980. Ljubljana, Biotechnical faculty: 115-120.
8. Eggum B.O., Kreft I., Javornik B. 1981. Chemical composition and protein quality of buckwheat (*Fagopyrum esculentum* Moench). Plant Food for Human Nutrition, 30:175-179.
9. Eskin N.A.M., Przybylski R., Malcolmson L.M., Ryland D., Mazza G. 1998. The effect of temperature and water activity on rutin, chlorophylls and colour of stored buckwheat. In: Advances in Buckwheat Research 7, IBRA, Winnipeg, Manitoba, Canada, III - 3-6.
10. Guezennec C.Y., Satabin P., Duforez F., Koziet J., Antoine J.M. 1993. The role of type and structure of complex carbohydrates response to physical exercise. International Journal of Sports Medicine 14:224-231.
11. Hagels H. 2007. Sekundäre Pflanzeninhaltsstoffe des Buchweizens; Die Wirkungen des Rutins; Gewinnung von Rutin aus Buchweizenblättern; In: Das Buchweizenbuch. Islek ohne Grenzen.
12. He J., Klag M.J., Whelton M.J., Mo J.-P., Chen J.-Y., Qian M.-C., Mo P.-S., 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.
13. Ikeda K. 1997. Molecular cookery science. In: Cookery Science for the 21 Century, Vol. 4, Kenpaku-Sha Press, Tokyo, Japan (in Japanese).
14. Ikeda K., Kishida M., Kreft I., Yasumoto K. 1997. Endogenous factors responsible for the textural characteristics of buckwheat products. J. Nutr. Sci. Vitaminol., 43:101-111.
15. Ikeda K., Arai R., Kreft I. 1998. A molecular basis for the textural characteristics of buckwheat products. In: Advances in Buckwheat Research 7, IBRA, Winnipeg, Manitoba, Canada, III - 57-60.
16. Ikeda S., Yamashita Y. 1994. Buckwheat as a dietary source of zinc, copper and manganese. Fagopyrum 14:29-34.
17. Javornik B., Kreft I. 1984. Characterisation of buckwheat proteins. Fagopyrum 4:30-38.

18. Kreft I., Jošt M., Škrabanja V. 1998. Genetic basis of wheat ideotype for special blended bread. In: Slinkard, A. E. (Ed.). Proc. 9th International Wheat Genetics Symposium, Saskatoon, Saskatchewan, Canada.
19. Kreft I., Luthar Z. 1990. Buckwheat - a low input plant. In: N. El Bassam et al. Genetic aspects of plant mineral nutrition, Kluwer Academic Publishers, 1990, p.497-499.
20. Kreft I. 1994. Traditional buckwheat food in Europe. Bulletin of the Research Institute for Food Science (Kyoto University) 57:1-8.
21. Kreft I., Bonafaccia G., Zigo A. 1994. Secondary metabolites of buckwheat and their importance in human nutrition. Prehrambeno-tehnol. Biotehnol. Rev. 32:195-197.
22. Kreft I., Škrabanja V., Ikeda S., Ikeda K., Bonafaccia G. 1996. Dietary value of buckwheat. - Research Reports UL, 67:73-78.
23. Kreft I., Fabjan N., Yasumoto K. 2006. Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. Food Chem., 98:508-512.
24. Luthar Z. 1992. Polyphenol classification and tannin content of buckwheat seeds (*Fagopyrum esculentum* Moench). Fagopyrum 12:36-42.
25. Michalova A. 1998. Study of relationships between yield and quality characters of common buckwheat (*Fagopyrum esculentum* Moench.). In: Advances in Buckwheat Research 7, IBRA, Winnipeg, Manitoba, Canada, I - 88-96.
26. Morrison W.R., Laignelet B. 1983. An improved colorimetric procedure for determining apparent and total amylose in cereal and other starches. J. Cereal Sci. 1:9-20.
27. Obendorf R.L. 1998. Buckwheat fagopyritols. In: Advances in Buckwheat Research 7, IBRA, Winnipeg, Manitoba, Canada, III - 65-71.
28. Olson O.E., Novacek E.J., Whitehead E.I., Palmer I.S. 1970. Investigations on selenium in wheat. Phytochemistry, 9.1181-1188.
29. Sathe S.K., Mason A.C., Weaver S.M. 1992a. Some properties of a selenium - incorporating sulfur-rich protein in soybeans (*Glycine max* L.). Journal of Agricultural and Food Chemistry, 40:2077-2083.
30. Sathe S.K., Mason A.C., Rodibaugh R., Weaver C.M. 1992b. Chemical form of selenium in soybean (*Glycine max* L.) lecitin. Journal of Agricultural and Food Chemistry, 40.2084-2091.

31. Skerritt J.H. 1986. Molecular comparison of alcohol-soluble wheat and buckwheat proteins. Cereal Chem. 63:365-369.
32. Steadman K., Obendorf R.L. 1998. The use of buckwheat bran milling fraction in bread. In: Advances in Buckwheat Research 7, IBRA, Winnipeg, Manitoba, Canada, III - 21-26.
33. Stibilj V., Dermelj M., Franko M., Byrne A.R. 1994. Spectrophotometric determination of the chemical yield in radiochemical neutron activation analysis of selenium. Analytical Sciences, 10:789-793.
34. Škrabanja V., Kreft I. 1998. Resistant starch formation following autoclaving of buckwheat groats. An in vitro study. J. Agr. Food Chem. 46:2020-2023.
35. Thompson L.U. 1993. Potential health benefits and problems associated with antinutrients in foods. Food Research International 26:131-149.
36. Wang Z., Xie S., Peng A. 1996. Distribution of Se in soybean samples with different Se concentration. Journal of Agricultural and Food Chemistry, 44:2754-2759.
37. Yasumoto K., Suzuki T., Yoshida M. 1988. Identification of selenomethionine in soybean protein. Journal of Agricultural and Food Chemistry, 36:463-467.

Author's addresses – Adrese autora:

Kreft Ivan and Mateja Germ
Biotechnical Faculty, University of Ljubljana,
Jamnikarjeva 101
1001 Ljubljana, Slovenia

Received - Primljeno:

May 25, 2008