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Review
Food Technology

Recent Advances in Processing and Development of Buckwheat Derived Bakery and Non-Bakery Products – a Review

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The functional food development is one of the most interesting fields of the food industry. The knowledge of the effects of processing is essential in order to optimize the conditions and to obtain functional foods rich in bioactive compounds. Many functional buckwheat derived bakery and non-bakery products have been put into production including buckwheat enhanced breads, biscuits, snacks, noodles, tea, tarhana, sprouts, and finally buckwheat honey. This article reviews the studies carried out in the past few years in relation to the effects of processing on bioactive compounds in buckwheat derived bakery and non-bakery products, and on their overall nutritional value and consumer acceptance. Finally, the future trends in buckwheat processing are addressed.

INTRODUCTION

The food industry is one of the most important branches of the economy in the European Union, playing a central role for the processing of agricultural raw materials and food supply [Bigliardi & Galati, 2013]. One of the most attractive trends is the development of new functional foods. Functional foods constitute those that exert a scientifically proven specific health benefit (health claim) beyond their nutritional properties but the consumption of their specific formulation is not essential for human life. Examples of functional foods include fortified beverages, juices, milk, yoghurts, margarines, cereals, *etc*. [González-Sarrías *et al*., 2013]. These products are of interest for an increasingly health-concerned society and may be especially relevant for preventing or delaying a number of age-related diseases [González-Sarrías *et al*., 2013]. Recently, buckwheat as a pseudocereal has received increasing attention as a potential functional food [Krkošková & Mrázová, 2005; Zhang *et al*., 2012]. Buckwheat has been used as an important raw material for functional food development because of its functionalities and compounds content, such as proteins, flavonoids, phytosterols, and other [Ötles & Cagindi, 2006]. Rutin, a secondary metabolite present in buckwheat, has shown anti-inflammatory, anticancer, antiatherogenic, and antioxidant activity [Kreft *et al*., 2006; Zhang *et al*., 2012]. Buckwheat protein extracts have been related to cholesterol-lowering and anticancer effects in animals [Liu *et al*., 2001; Tomotake *et al*., 2006]. Incorporation of buckwheat into bread has proved to significantly lower postprandial blood glucose and insulin responses compared to white wheat bread [Skrabanja *et al*., 2001]. D-*chiro*-inositol has been associated with reduction of symptoms of non-insulin-dependent diabetes mellitus [Kawa *et al*., 2003]. Therefore, obtaining different buckwheat-based bakery and non-bakery products with health-promoting components (fiber, antioxidants and/or minerals), the optimization of recipes and technological process parameters, and the characterization of final products in terms of sensory acceptance and potential functional properties, have acquired a considerable interest in the past few years [Burluc *et al*., 2012]. For this purpose, the sensory and technological quality of buckwheat-based bakery and non-bakery products have been improved substantially. Hence, buckwheat products such as bread, biscuits, snacks, noodles and cookies as well as tea, sprouts and honey, are currently commercialized and consumed [Hatcher *et al*., 2008]. Simplified diagrams of the buckwheat derived bakery and non-bakery products are presented in Figure 1 and 2, respectively. This article reviews the current knowledge regarding the effects of the different processing methods on the buckwheat bioactive compounds and advances in the development of functional buckwheat derived bakery and non-bakery products.

OVERVIEW OF BUCKWHEAT AS A SOURCE OF BIOACTIVE COMPOUNDS

There are many species of buckwheat in the world, with nine having mainly agricultural value. Generally, two types are used around the world: common buckwheat (*Fagopyrum*

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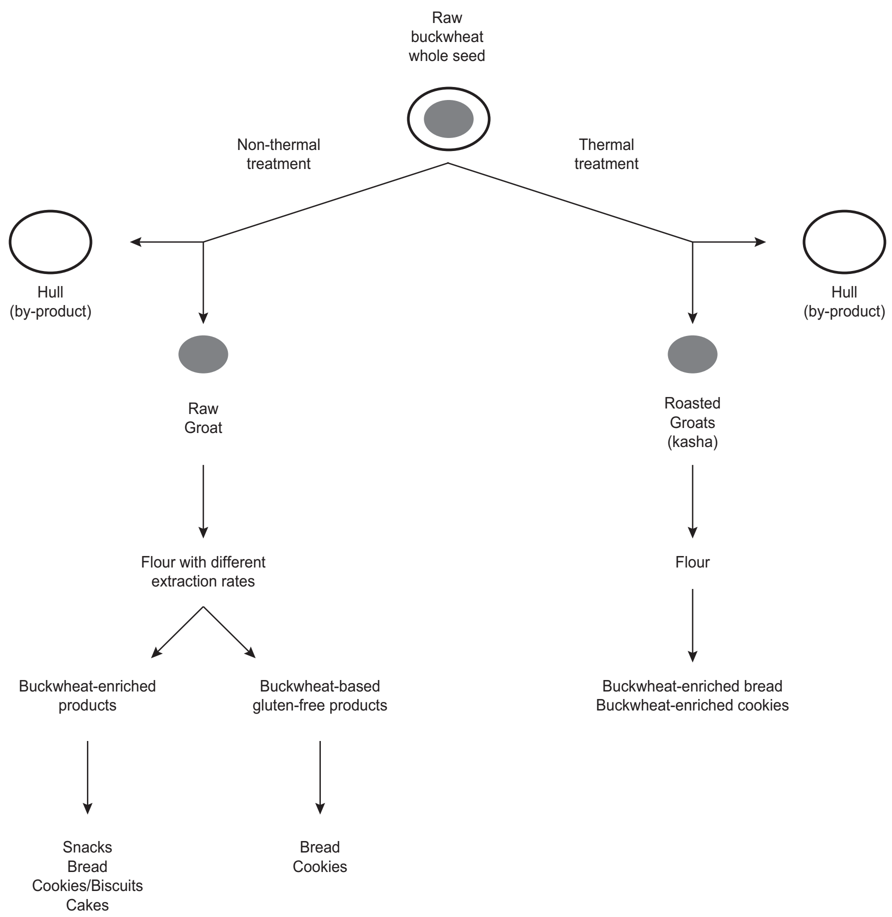

FIGURE 1. Simplified diagram of the buckwheat derived bakery products.

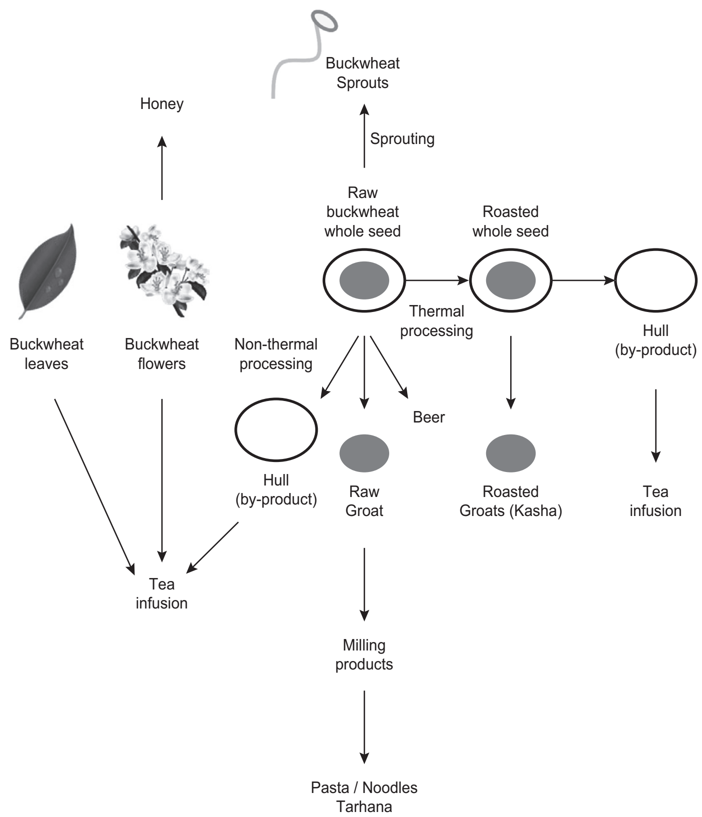

FIGURE 2. Simplified diagram of the buckwheat derived non-bakery products.

esculentum) and tartary buckwheat (*F. tataricum*). Buckwheat seeds have a triangular shape and are covered by a dark brown or black hull. They are mainly consumed in a dehulled form. Buckwheat seeds show a percentage of carbohydrates of 73.3%, with starch being the main component [Bonafaccia *et al*., 2003]. This pseudocereal is recognized as a good source of nutritionally valuable protein, lipid, dietary fiber and minerals. Buckwheat protein is rich in albumin and globulin, but very poor in prolamin and glutein. The high biological value of these proteins is due to well-balanced amino acid composition, being rich in lysine and arginine. Buckwheat flour is suitable for the use in celiac diet, because of its low non-toxic prolamine content [Alvarez-Jubete *et al*., 2009]. Both common and tartary buckwheat grains are a good source of unsaturated fatty acids, mainly oleic and linoleic acids [Bonafaccia *et al*., 2003; Wijngard & Arendt, 2006]. Bonafaccia *et al*. [2003] reported a dietary fiber content of 27.38% in buckwheat seeds. Buckwheat seeds contain very rare D-*chiro*-inositol, which is mainly found in the form of fagopyritols [Wijngaard & Arendt, 2006]. This compound has acquired a lot of interest due to its glucose-lowering capacity in animal models [Yao *et al*., 2008]. Buckwheat seeds, both groat and hull, and sprouts are

TABLE 1. Buckwheat bioactive compounds of a high interest for food industry.

Category	Compounds/distribution	Concentration	Reference
Phenolic compounds	Rutin/groats	80.94 mg/g in TB and 0.20 mg/g in CB	Steadman *et al.* [2001] Fabjan *et al.* [2003] Kim *et al.* [2004] Kalinova *et al.* [2006] Wijngaard & Arendt [2006] Zielińska & Zieliński [2009]
	Quercetin/groats	0.001 mg/g DW	
	Quercetin/hull	0.009-0.029 mg/g DW	
	Quercitrin/seeds	0.1-0.5 mg/g DW	
Inositol	Phytic acid/ bran without hull	35-38 mg/g	Steadman *et al.* [2001] Zielińska & Zieliński, [2009]
	D-*chiro*-inositol/groats		Yao *et al.* [2008]
Vitamins	Thiamine (vitamin B1)/seeds	2.2-3.3 μg/g DW	Bonafaccia *et al.* [2003] Wijngaard & Arendt [2006] Zielińska & Zieliński [2009]
	Riboflavin (vitamin B2)/seeds	10.6 μg/g DW	
	Niacin (vitamin B3)/seeds	18 μg/g	
	Pantothenic acid (vitamin B5)/seeds	11 μg/g	
	Pyridoxine (vitamin B6)/seeds	1.5 μg/g	
	Vitamin C/seeds	50 μg/kg DW	
	Vitamin C/sprouts	250 μg/kg DW	
Tripeptides	Glutatione/groats	1.1 μmol/g DW	Zielińska & Zieliński [2009] Gabrovska *et al.* [2002]
Lipophilic LMWA	Tocopherols (vitamin E)/groats	14.3-54.6 μg/g	Wijngaard & Arendt [2006] Kalinova *et al.* [2006]
	Carotenoids/seeds	2.1 μg/g DW	Zielińska & Zieliński [2009] Wijngaard & Arendt [2006]
Lipophilic LMWA: phytosterols	β-sitosterol/dehulled groats	0.7 mg/g DW	Normen *et al.* [2002]
	β-sitosterol/buckwheat flour	0.86 mg/g DW	
	Campesterol/groats	0.09 mg/g DW	
	Campesterol/ buckwheat flour	0.11 mg/g DW	
	Stigmasterol/groats	n.d.	
	Stigmasterol/ buckwheat flour	0.02 mg/g DW	
Lipophilic LMWA: hormones	Melatonin/groats	470 pg/g DW	Zielińska & Zieliński [2009]
Isoprenoid	Squalene/leaves	98.57 μg/g DW*	Kalinova *et al.* [2006]
Tannins	Condensed/bran	5.9 - 8.6 mg/g DW	Steadman *et al*. [2001] Zielińska & Zieliński [2009]
	Non-condensed/bran	2.3 - 3.8 mg/g DW	
	Proanthocyanidins/buckwheat flour	1.59 mg/g DW	
	Proanthocyanidins/hull	1.38 mg/g DW	

Low molecular weight antioxidants (LMWA); dry weight (DW); Tartary buckwheat (TB); Common buckwheat (CB); * According to Kalinova *et al.* [2006] this is the maximum concentration detected, but certain differences appear among different varieties of buckwheat.

an important source of rutin (quercetin-3-rutinoside) the content of which depends on the variety of seeds and growth conditions [Zielińska & Zieliński, 2009]. Along with rutin, a high content of epicatechin in flowers and leaves make these parts of buckwheat good antioxidant sources in human diet [Kalinova *et al*., 2006]. The *C*-glucoflavones present mainly in buckwheat seeds are vitexin, isovitexin, orientin and homoorientin, which exert antioxidant activity *in vitro* [Zielińska & Zieliński, 2011]. Quercetin, the aglycone of rutin, is a flavonoid with a potent antioxidant activity that is present in buckwheat groats in a lower concentration [Zielińska & Zieliński, 2009]. Tannins isolated from buckwheat showed a relatively high level of activity against *Listeria monocytogenes* [Amarowicz *et al*., 2008]. The bioactive compounds of a high interest for food industry are compiled in Table 1. Recently, γ-aminobutyric acid (GABA) and 2"-hydroxynicotianamine (2HN) have been found to serve as functional compounds in buckwheat. Seeds and sprouts contain GABA, while 2HN has been recently identified in buckwheat flour [Aoyagi, 2006]. *In vitro* and *in vivo* studies have shown that the consumption of buckwheat and buckwheat enriched foods is related to a wide range of biological and pharmacological activities: hypocholesterolemic, hypoglycemic, anticancer and anti-inflammatory [Zhang *et al*., 2012]. These beneficial effects have been associated with a high antioxidant capacity of buckwheat, which is attributed mainly to their phytochemicals [Zielińska *et al*., 2010]. Therefore, in order to obtain potentially functional buckwheat food of high nutritional quality, it is important to understand the effect of processing on bioactive compounds. Hence, it is of utmost importance for the food industry to seek out more effective and optimized methods to reduce undesirable changes in foods associated with food processing.

PROCESSING

It is well known that processing can induce chemical changes in food products, therefore, it is important to consider the effects on the bioactive compounds of buckwheat. Nowadays, there are multiple technological processes related to buckwheat.

Thermal processing

The studies that investigate the effects of thermal processing on buckwheat-derived food have been intensified considerably. Many new thermal techniques are being employed in the food industry in order to improve the quality of buckwheat functional food. Extrusion processing has become an important food process in the production of pasta, ready-to--eat cereals, snacks, pet food, and textured vegetable protein. Microwave heating has gained popularity in food processing due to its ability to achieve high heating rates, significant reduction in cooking time, more uniform heating and safe handling. This technique might change flavor and nutritional qualities of food to a less significant extent as opposed to conventional heating during the cooking process [Chandrssekaran *et al*., 2013]. However, the data on the effect of thermal treatments on the antioxidant capacity of buckwheat and its products are still limited. Most of the studies focused on the determination of the effect of heat treatment on total phenolic and flavonoid content, and antioxidant capacity due to its role in human health and disease management.

Heat treatment of buckwheat was found to evoke changes in its chemical composition and, above all, to affect the functional properties of selected bioactive compounds. The results about the effect of the thermal treatment on buckwheat seeds and processed flour that have been published are contradictory. After thermal processing, common buckwheat groats and cakes were shown to have a detrimental effect on flavonoid which might reduce the antioxidant capacity [Kreft *et al*., 2006]. Similar results were observed in tartary buckwheat bread during its elaboration [Vogrinćić *et al*., 2010]. In addition, Sensoy *et al*. [2006] reported that antioxidant activity of buckwheat flour was decreased by roasting but not after extrusion treatment. On the contrary, Randhir *et al*. [2008] found, after autoclaving treatment, an increase in the total antioxidant activity in sprouts and seeds. In addition an increase of 20% and a decrease of 7% of total phenolic compounds in sprouts and seeds, respectively, were observed. Contradictory results were also found by Zieliński *et al*. [2006] in extruded groats, which showed a reduction in the antioxidant capacity accompanied by a decrease in rutin and isovitexin, but at the same time an increase in free phenolic acids and those released from ester bonds.

It has been recognized that the possible beneficial effects of buckwheat phytochemicals may be related to the inherent antioxidant capacity of these compounds. Therefore, the relation between the antioxidant capacity and these compounds after thermal treatment has been addressed during the last decade. Zieliński *et al*. [2009] related the antioxidant capacity of buckwheat products to the concentration of flavonoids after hydrothermal treatment. Kreft *et al*. [2006] described significant correlations between rutin content and the antioxidant activity of buckwheat seeds and buckwheat-based food products, respectively. Zhang *et al*. [2010] reported a decrease in the antioxidant capacity of tartary buckwheat flour accompanied by a reduction of the content of total flavonoids and total phenolics after roasting, microwave and especially pressure-steaming heating. These results showed that phenolics act as the main antioxidant compounds in tartary and common buckwheat. However, Şensoy *et al*. [2006] reported contradictory results, describing a reduction in the antioxidant capacity but no significant changes in total phenolic compounds after roasting. Apart from phenolics, other compounds, such as proteins, appear to be included in the formation of antioxidant capacity of buckwheat products. Zieliński *et al*. [2009] reported that roasting groats showed a decrease in the antioxidant capacity along with a decrease in the protein quality and content in groats. Furthermore, during thermal treatment, Maillard compounds are generated due to a chemical reaction between free amino groups of lysine and carbonyl groups of reducing sugars [Delgado-Andrade, 2014]. Zieliński *et al*. [2009] observed the formation of Maillard products induced by the thermal treatment of both whole seeds and groats. Although Maillard compounds might be harmful for health, they can contribute to an increase in the antioxidant activity, masking the real decrease in the total phenolic compounds [Zielinski *et al*., 2009; Zhang *et al*., 2010]. Furthermore, it has been proposed that the antioxidant capacity can be increased as a result of the disassociation of phenolics forms and liberation of phenolics bounded to cell walls due to thermal processing followed by some polymerization/oxidation of the phenolic constituents, or the by-products generated [Randhir *et al*., 2008].

These contradictory results obtained point out to the importance of determining the exact composition and ratio of bioactive compounds. Furthermore, more studies are necessary to recognize the effect of thermal processing on functional compounds, including protein and phenolic compounds, of buckwheat products in order to obtain buckwheat of consumption quality. Therefore, processing conditions, such as time and temperature should be optimized to maintain the functionality of bioactive compounds.

High pressure

High pressure (HP) has been shown to offer a viable alternative to thermal processing, with no negative effects such as off-flavor formation, vitamin and phytochemical properties loss, and discoloration [Norton & Sun, 2008]. Błaszczak *et al*. [2013] observed that after HP treatment the antioxidant capacity and rutin content differed in case of raw and roasted buckwheat groats. The pressurization of roasted groats increased the total reducing capacity formed by hydrophilic antioxidants by 18% when measured by cyclic voltammetry method on average and decreased the concentration of rutin after treatment. In contrast, the reducing capacity decreased in the case of raw buckwheat, whereas rutin content dropped at shorter times than roasted groats. To the best of our knowledge, this study is the first that investigates the effect of HP on bioactive compounds of buckwheat. Even so, contradictory effects were observed. Therefore, necessary further studies investigating the effect of pressurization on bioactive compounds are required to determine which conditions are the most adequate to produce high-quality buckwheat products.

Ionization and radiation

Food irradiation is a method of treating food in order to make it safer to eat and to extend its shelf life. Traditionally, this process has been used to control surface microorganisms on vegetables and fruits without affecting the nutritional quality. Hayashi *et al*. [1998] reduced the microbial load to a lower level, exposing buckwheat grains to low-energy electrons (soft--electrons) without affecting their quality. Recently, there have been published studies where aqueous chlorine dioxide, fumaric acid, modified atmosphere packaging enriched in CO_2, and ultraviolet (UV)-C radiation were combined to treat buckwheat sprouts for improving the microbial quality. Reductions of total aerobic bacteria, yeast and mould, and enterobacteria up to low levels without affecting the sensory quality were observed. However, an increase in the concentration of rutin was shown after treatment [Chun & Song, 2013].

A comparative study carried out by Orsák *et al*. [2001] reported the effect of UV, microwave and γ-irradiation on three buckwheat samples. Different effects were observed depending on the irradiation system and dose applied on the polyphenol and rutin content. Furthermore, it has been described that rutin and flavones *C*-glucosides are enhanced in sprouts after exposition to light emitting diodes [Hossen, 2007]. Therefore, irradiation could offer a method to increase the half-life of food, maintaining the sensorial quality, improving the microbial quality and enhancing the nutritional value due to the increase in the bioactive compounds in buckwheat-derived products. Although public knowledge about irradiation continues to be limited, the interest in purchasing safety-enhanced irradiated food is increasing, especially after people's gaining information about potential benefits and risks.

BUCKWHEAT DERIVED BAKERY FOOD

Buckwheat groats

Buckwheat grain constitutes the main form in which buckwheat is consumed. Dehulled seeds (raw groats) are principally used for human consumption as breakfast cereals, or as processed flour for making different products (Figure 1). The roasted groats, also known in Central and Eastern Europe as "kasha", are ready for cooking and usually served as an alternative to potatoes and rice [Wijngaard & Arendt, 2006]. To obtain good-quality roasted groats the dehulling process is preceded by raising the moisture content of the raw whole seeds and followed by simultaneous steaming and heating.

Bakery products

In the bakery industry there is a tendency to develop innovative bakery products by using the health-promoting role of buckwheat. The bioactive components present in the buckwheat flour show multiple beneficial effects on health [Zielińska & Zieliński, 2009]. Therefore, the elaboration of different bakery products (bread, noodles, biscuits) from raw materials with potential functional components, the optimization of process parameters and recipes, and the characterization of final products in terms of sensory and physicochemical properties are acquiring a considerable interest.

Buckwheat-enhanced wheat bread

Wheat bread represents a staple food for the majority of the world population and contributes substantially to the intake of several nutrients. Buckwheat, added to food as a supplement, can prevent food from oxidation during processing. Lin *et al*. [2009] showed that wheat flour enriched with 15% of husked or unhusked buckwheat flour exhibited higher content of sugar, more free amino acids, higher flavor 5'-nucleotides, and 2 – to 3-fold higher total volatile content in comparison to wheat bread. This research indicated that buckwheat flour could be incorporated into bread recipe, providing buckwheat-enriched wheat bread with more sugars, a stronger umami taste and a more characteristic aroma. Bojňanská *et al*. [2009] reported that a substitution of 30% wheat flour with buckwheat flour yielded a buckwheat-enhanced wheat bread acceptable from the technological, sensory and health point of view. Vogrinćić *et al*. [2010] described an increase in the antioxidant activity and rutin content in dough and breads with a growing percentage of tartary buckwheat flour. Tartary buckwheat flavones have been used to enrich wheat bread [Gawlik-Dziki *et al*., 2009]. Chlopicka *et al*. [2012] reported that buckwheat-enriched wheat bread had the highest phenolic content and antioxidant activity in comparison with amaranth and quinoa enriched wheat bread. It has been reported that buckwheat-enriched wheat bread can inhibit *in vitro* the formation of advanced glycation end--products (AGEs) [Szawara-Nowak *et al*., 2014]. Moreover, Bojňanská *et al*. [2009] showed an increase in the plasma antioxidant capacity after four weeks of 30% buckwheat-enriched wheat bread consumption. The research also showed that the addition of buckwheat increased the content of proteins, minerals, fibers as well as rutin in bread. In addition, buckwheat, along with other pseudocereals, has been proposed as an alternative source to increase the folate content in staple foods, such as bread, pasta and cookies [Schoenlechner *et al*., 2010]. In the recent studies it has been reported that the use of whole buckwheat flour in the elaboration of Turkish flat bread, lavaş, increased the content of fiber, phytic acid, Fe, K, Mg and P contents [Yildiz & Bilgiçli, 2012].

The use of buckwheat flour as a bakery raw material is limited because there is no glutenin and gliadin fraction for gluten formation. According to Bojňanská *et al*. [2009], the rheological properties of dough change when the amount of buckwheat in the blend is increased. It was shown that *e.g.* prolongation of the dough development time required more energy input and longer kneading period. In an attempt to assess guidelines for novel recipes for obtaining bread from wheat and buckwheat flour blends with improved nutritional properties, some authors have investigated different buckwheat-enriched wheat bread formulations to increase the diversity, nutritional value and product appeal. It has also been described that addition of buckwheat hull hemicelluloses (0.3–0.5%) obtained from seeds to the wheat flour had positive effects on the bread quality, contributing to higher scores for product overall acceptability [Hromádková *et al*., 2007].

Sourdough fermented buckwheat enhanced wheat bread

Buckwheat sourdough, obtained through long fermentation of buckwheat flour carried out with naturally occurring lactobacilli and yeasts, gained attention for wheat bread production [Moroni *et al*., 2012]. A starter culture is microbial preparation of cells, added to a raw material to produce fermented food by accelerating and driving this fermentation process [Coda *et al*., 2014]. Therefore, appropriate starter cultures and process parameters have started to be exploited in buckwheat sourdough [Moroni *et al*., 2011a]. The application of the strains *Lactobacillus fermentum* AB 15, *L. plantarum* AB 16, *L. vaginalis* AB 17 and *L. crispatus* AB 19 improved the quality of the product. Acidification, aroma formation and leavening were the main functions of lactic acid bacteria and yeasts. The fermentation applied to obtain buckwheat sourdough decreased the content of phytic acid of buckwheat flour, without hindering the nutritional properties of buckwheat. The incorporation of buckwheat sourdough in wheat bread also improved the crumb structure and volume of the bread, alongside with prolonged shelf life and increased content of polyphenols [Moroni *et al*., 2012]. However, it has been documented that buckwheat sourdough showed a decrease in the network connectivity, and exhibited reduced elasticity. Furthermore, the sourdough bread had a lower volume and a harder crumb [Moroni *et al*., 2011b]. Recently, *Lactobacillus delbrueckii* subsp. lactis has been described to increase the total phenolic content and the antioxidant capacity in buckwheat sourdough [Gandhi & Dey, 2013].

Buckwheat biscuits and snacks

Recently there has been observed an increased consumer demand for composite flour based bakery products such as biscuits, snacks or cereals. Buckwheat enriched biscuits and snacks are new buckwheat derived products. Wójtowicz *et al*. [2013] showed a good acceptability of buckwheat enriched snacks, at a level no higher than 30%, proposing corn-buckwheat snacks as an attractive type of appetizer with increased nutritional properties. Addition of buckwheat flour into biscuit formulation exerted considerable effects on physicochemical and sensory properties of biscuits. The biscuits enriched with buckwheat had increased spread, hardness and fracturability [Filipčev *et al*., 2011]. Baljeet *et al*. [2010] successfully incorporated buckwheat flour into refined wheat flour biscuits up to a level of 20% to yield biscuits of enhanced nutritional quality with acceptable sensory attributes. In a study carried out by Filipčev *et al*. [2011], the sensory analysis of ginger nut biscuits, popular traditional biscuits containing honey, indicated that addition of 40% buckwheat flour was the best scored, but 50% provided a sensory acceptable product with enhanced bio-functional properties. Furthermore, a significant increase in protein, dietary fibre, total polyphenols, antioxidative and chelating activity and macro – and microelements contents was reported.

Buckwheat noodles

Buckwheat noodles, also known as soba noodles, are normally made from a blend of common wheat flour and buckwheat flour. The Japanese Food Agency stipulates that a minimum of 35% buckwheat must be present for noodles to be called soba noodles [Hatcher *et al*., 2011]. Most of the soba noodles contain at least 60% of buckwheat, although some handmade soba noodles are made with 100% buckwheat flour [Hatcher *et al*., 2008]. The noodles are consumed both hot and cold, with the most common type, – mori soba – being boiled and eaten cold with sauce [Hatcher *et al*., 2011]. Soba noodles often have additional ingredients, such as green tea powder [Haraguchi *et al*., 2003], shiitake mushroom or seaweed [Yoon *et al*., 2007].

The texture of food constitutes an important quality attribute which affects consumer acceptance and preference for a particular food product [Hatcher *et al*., 2011]. It has been described that texture of noodle depends primary on its starch, fibre and protein contents. Hatcher *et al*. [2011] described a superior noodle texture elaborated with a tartary buckwheat blend, which showed lower protein content, yet higher quality. Van Hung *et al*. [2007] used a gradual milling method in which whole buckwheat grains, from outer to inner parts, were used for noodle making, substituting the 40% of wheat flour. The outer buckwheat fractions, which contain lower amount of starch, higher protein and dietary fibre content than inner parts, had softer and improved texture, with the optimum cooking time being lower than that elaborated with inner fractions.

TABLE 2. The content of phytochemicals in buckwheat noodles[1].

Buckwheat variety	Compounds	Content[2,3]
Tartary	Rutin	37.1-48.2 mg/100g DW
	Quercetin	392-455.5 mg/100 g DW
	Ellagic acid	130.06-255.1 mg/100 g DW
	p-Hydroxybenzoic acid	533.1-715.1 mg/100 g DW
	Chlorogenic acid	230.9±2 mg/100 g DW[2]
	Feluric acid	108.3±7.2 mg/100 g DW[2]
	Protocatechuic acid	975.0-3006.1 mg/100 g DW
	Catechin	269.9±15.6 mg/100 g DW[2]
Common	Rutin	1.2-7.8 mg/100 g DW
	Quercetin	2.1-5.7 mg/100 g DW
	Ellagic acid	238.2-266.8 mg/100 g DW
	p-Hydroxybenzoic acid	28.4-43.8 mg/100 g DW
	Chlorogenic acid	410.8-1285.8 mg/100 g DW
	Feluric acid	74.3-127.4 mg/100 g DW
	Protocatechuic acid	107.6-389.2 mg/100 g DW
	Catechin	503.7-1172.2 mg/100 g DW
	Cinnamic acid	2.6±0.6 mg/100 g DW[2]
	p-Coumaric acid	6.6-135.4 mg/100 g DW
	Syringic acid	280.4-348.6 mg/100 g DW
	Gallic acid	27.9-40.7 mg/100 g DW

Abbreviations: DW, dry weight. [1]Kreft *et al.* [2006]; Ma *et al.* [2013]; [2]The range of concentration is given for different varieties; [3]Detected only in one variety.

The incorporation of buckwheat flour to soba noodles modifies the nutritional and sensorial quality of this product. Buckwheat noodles elaborated with the inner buckwheat flour fractions (40%) exhibited more white and less yellow color, lower content of phenolic compounds, lower amount of protein and dietary fibre, and higher amount of starch, in comparison to noodles obtained after substitution with outer fractions [Van Hung *et al*., 2007]. Hatcher *et al*. [2008] compared the potential of different buckwheat varieties for elaborating soba noodles, and the effect of buckwheat flour refinements (white flour, whole groat, and dark flour) on the composition, appearance and texture of the products. Noodles prepared with white flour were marked by the best chewiness and springiness, while those elaborated with dark flour contained considerably higher amounts of minerals, proteins, dietary fibre, and fagopyritols. Similar results were documented by Bilgiçli [2008] who described an increase in K, Mg, and P amounts in darker noodles after addition of 40% whole buckwheat flour to Turkish noodles. Furthermore, the final product was appreciated by the panelists, especially noodles containing up to 25% of whole buckwheat flour. Ma *et al*. [2013] indicated that common buckwheat noodles, compared to the faint yellow of tartary buckwheat, were more accepted by the panelists. In this study, the overall acceptability evaluation revealed that common buckwheat noodles were more acceptable than tartary noodles. Furthermore, an increase in the antioxidant capacity in buckwheat noodles was reported, being the phenolic acid and flavonoid composition varying depending on the species of buckwheat used (Table 2).

Different authors have investigated the effect of processing on the bioactive compounds of soba noodles. Higasa *et al*. [2011] documented that the content of 2”-hydroxynicotianamine (2-HN), a recently discovered angiotensin I-converting enzyme (ACE) inhibitory compound which may help to reduce hypertension, ranged from 16 – 28 mg per 100 g of dry weight in dried buckwheat noodles. Although the concentration of 2-HN in noodles was reduced after boiling, soba noodles may be a source of this compound to be incorporated in the diet. In a recent study it has been reported that incorporation of buckwheat into the noodles resulted in product with softer texture, less color and higher content of rutin and quercetin [Choy *et al*., 2013]. In regard to the rutin content, during processing, attention should be put to the factors which may decrease the concentration of this compound. Kreft *et al*. [2006] showed a decrease in the concentration of rutin in buckwheat noodles after processing. This reduction was associated with the hydrothermal treatment, combination with other molecules, and/or presence of rutin degrading enzyme flavonoid 3-glucosidase. In contrast, Yoo *et al*. [2012] documented that hydrothermal treatment minimized rutin loss in tartary buckwheat flour and in noodles containing hydrothermally-treated buckwheat flour.

In addition to bioactive compounds, several studies have investigated the effects of different processing methods on different quality parameters. Ono *et al*. [2007] reported that superheated steam, a type of saturated (dry) steam generated by the addition of sensible heat to saturated (wet) steam [Head *et al*., 2010], unaffected the color tone of buckwheat flour or the sensory characteristics of buckwheat noodles, suggesting that this treatment may be useful for processing this product with a view to increasing flavor and preservation. Li *et al*. [2008] improved the textural and cooking quality of fried instant buckwheat noodles using triglycerides (TG). Hara *et al*. [2009] described that addition of buckwheat sprouts to the buckwheat noodle formula resulted in decreasing of resistance to the mastication. The flavor generation mediated by lipase and peroxidase in buckwheat flour was analyzed by Suzuki *et al*. [2010] in order to select varieties with improved flavor and to increase desirable flavor of buckwheat products. Bilgiçli [2008] showed that after fermentation of buckwheat grains by fungi *Rhizopus oligosporus* the amount of amino acids, minerals was higher and allergenic proteins were reduced as compared to non-fermented material. Moreover, the concentration of GABA was increased, while phytic acid was reduced approximately to 70–90%, being a desirable effect since increasing concentrations of buckwheat flour may increase the concentration of this anti-nutrient. Furthermore, cooked noodles elaborated with fermented buckwheat flour became more elastic and softer, with the colors being more brownish than those elaborated with non-fermented buckwheat flour.

TABLE 3. The content of phytochemicals in honeys from common buckwheat.

Compounds	Content[1]
Protocatechuic acid*	14.1-127.0 μg/100 g FW
p-Hydroxybenzoic acid*	92.4-888.1 μg/100 g FW
p-Hydroxyphenil acetic acid*	24.6-221.4 μg/100 g FW
Caffeic acid*	53.0-214.6 μg/100 g FW
Syringic acid*	31.7-45.3 μg/100 g FW
p-Coumaric acid*	58.5-1297.1 μg/100 g FW
Ferulic acid*	60.2-249.5 μg/100 g FW
Isoferulic acid*	35.6-97.2 μg/100 g FW
Benzoic acid*	39.5-288.4 μg/100 g FW
Abscisic acid*	18.6-381.4 μg/100 g FW
Quercetin**	8.8-88.3 μg/100 g FW
Apigenin**	13.8-56.5 μg/100 g FW
Pinobanksin***	10.8-250.1 μg/100 g FW
Kaempferol**	14.5-63.2 μg/100 g FW
Isorhamnetin**	15.8-40.9 μg/100 g FW
Chrysin**	19.2-128.2 μg/100 g FW
Pinocembrin***	11.1-117.6 μg/100 g FW
Galangin**	10.9-54.6 μg/100 g FW

Abbreviations: FW, fresh weight. [1]The range of concentration is given for different varieties. According to Pasini *et al.* [2013] the concentrations were calculated: *as ferulic acid at λ=280 nm; **as chrysin at λ=330 nm; ***and as chrysin at λ=280 nm.

Non-bakery products

Buckwheat honey

Buckwheat honey is a reddish brown product with a strong animal aroma [Vit *et al*., 2010] and low viscosity [Juszczak & Fortuna, 2006]. It has been demonstrated that honey serves as a source of natural antioxidants (Table 3). Comparative studies described that buckwheat honey has higher antioxidant capacity, as well as flavonoid and total phenolic content than other honeys [Nagai *et al*., 2001, 2006; Vit *et al*., 2010; Wilczyńska, 2010; Socha *et al*., 2011]. Pasini *et al*. [2013] compared 10 buckwheat honey samples with *p*-coumaric acid (29.5%) and *p*-hydroxibenzoic acid (21%) being the main components. Buckwheat honey has been used as a protective agent against lipid oxidation in ground turkey [McKibben & Engeseth, 2002]. It has been also used as an inhibitor of heterocyclic aromatic amine formation in fried ground patties [Shin *et al*., 2003], fried beef steak and chicken breast [Shin & Ustunol, 2004]. In addition, it has been described to be a potent inhibitor of the growth of foodborne pathogens and food spoilage organisms [Mundo *et al*., 2004; Nagai *et al*., 2006]. Brudzynski & Kim [2011a] described an increase ininhibitory activity of buckwheat honey against *Bacillus subtilis* and *Escherichia coli* after 3–6 months of storage. In this sense, the use of honey as a natural antioxidant instead of traditional antioxidants used in the food industry, such as butylated hydroxyl anisole (BHA) or propyl gallate (PG), could contribute to public health and the economics of food production.

Commercial honey processing includes controlled heating to destroy yeast and to dissolve dextrose crystals, combined with fine straining or pressure filtration. The impact of industrial processing and storage on the antioxidant capacity of honey is not understood well. Wang *et al*. [2004] indicated that processing dramatically reduced antioxidant capacity of buckwheat honey by 33.4% as compared to raw ones. Additional reduction of antioxidant capacity of processed honey was noted after storage for a long period, for example 6 months. Similar results were observed by Kowalski [2013] who reported a decrease in the antioxidant capacity of buckwheat honey after different thermal treatments. Wang *et al*. [2004] proposed that the reduction in the antioxidant capacity may be due to the reduction in phenolics. These authors observed the reduction of total phenolics of buckwheat honey (vanillic acid or *p*-hydroxibenzoic acid) by 37%. Furthermore, the use of filters, such as celite, during honey filtration may have nonspecifically bound phenolics, which can explain (at least partially) the reduction of the antioxidant capacity. Other compounds generated during thermal treatment of buckwheat honey, such as hydroxymethylfurfural (HMF), melanoidins, and other Maillard reaction products, may influence the antioxidant activity [Brudzynski & Miotto, 2011b] and should be taken into account.

Buckwheat honey has proven to be an effective antioxidant which may be used as a source of natural antioxidants. The optimization of different steps during the elaboration of this product is essential to minimize the loss of antioxidant capacity. However, the low number of studies and the contradictory results described, point out the necessity of running more investigations with a view to obtain a high-quality product.

Buckwheat tea

Buckwheat tea is a popular health product in Asian and European countries [Qin *et al*., 2011; Zielińska *et al*., 2013]. Buckwheat tea can be made of common or tartary buckwheat [Zielińska *et al*., 2009; Qin *et al*., 2013]. Park *et al*. [2000] investigated the effect of boiling on rutin content in tea made from flowers and dried leaves of different species of buckwheat. Furthermore, buckwheat hulls, a by-product derived from the production of buckwheat products, has been also used for elaborating infusions [Zielińska *et al*., 2013]. The content of rutin (Table 4) and the inhibitory activity against formation of advanced glycation end products (AGEs) was higher in tartary buckwheat tea [Zielińska *et al*., 2009; Qin *et al*., 2013] than in common buckwheat tea [Zielińska *et al*., 2013]. Due to the low number of studies on this issue, further investigations are needed to explain the changes observed. Although it has been described that the buckwheat tea shows lower antioxidant capacity and lower content of total phenolic compounds than the green tea, this product may be offered to the consumers as a new type of tea enriched in flavonoids, especially rutin and other compounds, such as quercetin and flavone *C*-glucosides. Therefore, the buckwheat groat or hull may be used for tea

TABLE 4. The content of phytochemicals in buckwheat sprouts[1] and teas[2].

Buckwheat variety	Type of product	Compounds	Content
Sprouts[1]			
Common	Whole grain	Rutin	2772.9 mg/100 g DW
Tea			
Tartary	Without bran	Rutin	11184±0.1 mg/g DW
		Isoquercitrin	0.56±0.02 mg/g DW
		Quercetin	0.36±0.02 mg/g DW
		Kaempferol	0.09±0.01 mg/g DW
	Unhusked	Rutin	32855.3±0.4 mg/g DW
		Quercetin	2792.2±1.9 mg/g DW
		Homoorientin	84.4±0.4 mg/g DW
		Orientin	59.1±0.8 mg/g DW
		Vitexin	48.9±0.9 mg/g DW
		Isovitexin	36.5±0.4 mg/g DW
Common	Hull infusion	Rutin	62.8±0.9 mg/g DW
		Quercetin	n.d.
		Homoorientin	7.1±0.4 mg/g DW
		Orientin	26.7±0.7 mg/g DW
		Vitexin	64.7±0.8 mg/g DW
		Isovitexin	10.1±0.2 mg/g DW

Abbreviations: DW, dry weight; n.d., no detected. [1]Kim *et al.* [2004]; [2]Zielińska *et al.* [2009, 2013]; Qin *et al.* [2013]; [3]This concentration is related to sprout after 8 days of seedling.

preparation as the main single tea ingredient or as a mixed component of other tisanes.

Buckwheat tarhana

Tarhana is a traditional fermented cereal food, prepared by mixing wheat products, yoghurt, some vegetables and spices. The addition of buckwheat improved the nutritional contents of this soup in terms of fat, ash, protein, mineral (K, Mg, P) and lysine content. Moreover, phytic acid losses were found above 89% in all formulations studied. Higher buckwheat flour addition levels negatively affected fermentation loss, color values, water and oil absorption capacity of tarhana, being 40% of the optimal concentration to yield a product with adequate physical, functional and sensorial properties [Bilgiçli, 2009a,b].

Buckwheat sprouts

Sprouting is a simple way to obtain a product with highly enhanced antioxidative capacity, stemming most likely from rapidly biosynthesised low molecular antioxidants and phytochemicals (Table 4) [Kim *et al*., 2004; Álvarez-Jubete *et al*., 2010]. Increased level of phytochemicals in sprouts is important for aiding in the prevention of human diseases and/or in health maintenance [Brinskin, 2000; Espín *et al*., 2007]. Kim *et al*. [2004] used the mass production system to harvest buckwheat sprouts. After 7 days of seedling, rutin and quercetrin concentrations were notably increased, and chlorogenic acid was moderately enhanced. Furthermore, important quantities of vitamin C, linoleic acid (C18:2), and free amino acids (lysine, GABA and sulfur containing amino acids) were reported. In 2009, Peng *et al*. improved the nutritional status of buckwheat sprouts, substituting the cultivation method. The acceleration and maximization of precious nutrient levels such as rutin, total phenolic content, linoleic acid, ascorbic acid and GABA was more efficient. In 2010, Álvarez-Jubete *et al*. investigated polyphenol composition and antioxidant properties of methanolic extracts from buckwheat after sprouting. In this case, the germination time was 96 hours, and each seeds were subjected to alternating wet and dry cycles of 3 hours over 24 hours. Following sprouting the phenol content was two times higher (670.2 mg GAE/100 g) and the antioxidant capacity was increased.

To sum up, changes due to sprouting are desirable from a nutritional point of view, with the pseudocereal sprouted -seeds being nutritionally superior compared with the non-sprouted seeds. However, more studies are necessary to find out the optimal culture conditions to enhance the concentration of nutrients and to obtain healthier sprouts.

CONCLUSIONS AND FUTURE TRENDS

Recently, new consumer demands have emerged for food products with improved nutritional values or health benefits, posing new challenges also for the food industry. In this sense, the main trends might be:

- Stimulating progress in agriculture through selection of raw materials and optimization of production process. Research on safety, composition and nutritional value of new food products perceived as components of a balanced diet.
- Further studies examining simultaneously the effect of processing on bioactive compounds during buckwheat products elaboration, and the possible beneficial effects of the consumption of these products will contribute to determination of which conditions are the most adequate during the elaboration of buckwheat-derived food to produce products with high health-promoting properties.
- Efficient exploitation of the buckwheat by-products. Many buckwheat by-products are rich in nutrients. Therefore, the development of functional products, such as buckwheat tea, with the use of buckwheat by--products should be in progress.
- Extending the national and world market with new healthy products of high nutritional value. According to Khan *et al*. [2013] the emergence of a new market segment called “Health and Wellness” reached a global value of US$ 625 billion in 2012. Over the last two decades, different food branches have been motivated to enter this lucrative market. In this sense, the development of new functional foods and healthy products is one of the most attractive trends for the food indus-

try. Inter-industry relationships and research-oriented networks have to be proposed as factors which facilitate successful development of functional buckwheat derived bakery and non-bakery food products.

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REFERENCES

1. Álvarez-Jubete L., Wijngaard H., Arendt E.K., Gallagher E., Polyphenol composition and *in vitro* antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. Food Chem., 2010, 119, 770–778.
2. Alvarez-Jubete L., Arendt E.K., Gallagher E., Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. Int. J. Food Sci. Nutr., 2009, 60 (S4), 240–257.
3. Amarowicz R., Dykes G.A., Pegg R.B., Antibacterial activity of tannin constituents from *Phaseolus vulgaris*, *Fagoypyrum esculentum*, *Corylus avellana* and *Juglans nigra.* Fitoterapia, 2008, 79, 217–219.
4. Aoyagi Y., An angiotensin-I converting enzyme inhibitor from buckwheat (*Fagopyrum esculentum* Moench) flour. Phytochemistry, 2006, 67, 618–621.
5. Baljeet S.Y., Ritika B.Y., Roshan, L.Y., Studies on functional properties and incorporation of buckwheat flour for biscuit making. Int. Food Res. J., 2010, 17, 1067–1076.
6. Bigliardi B., Galati F., Innovation trends in the food industry: The case of functional foods. Trends Food Sci. Tech., 2013, 31, 118–129.
7. Bilgiçli N., Utilization of buckwheat flour in gluten-free egg noodle production. J. Food Agric. Environ., 2008, 6, 113–115.
8. Bilgiçli N., Effect of buckwheat flour on chemical and functional properties of tarhana. LTW-Food Sci. and Technol., 2009a, 42, 514–518.
9. Bilgiçli N., Enrichment of gluten-free tarhana with buckwheat flour. Int. J. Food Sci. Nutr., 2009b, 60, 1–8.
10. Błaszczak W., Zielińska D., Zieliński H., Szawara-Nowak D., Fornal J., Antioxidant properties and rutin content of high pressure-treated raw and roasted buckwheat groats. Food Bioprocess Tech., 2013, 6, 1, 92–100.
11. Bojňanská T., Frančáková H., Chlebo P., Vollmannová A., Rutin content in buckwheat enriched bread and influence of its consumption on plasma total antioxidant status. Czech J. Food Sci., 2009, 27, 236–240.
12. Bonafaccia G., Marocchini M., Kreft I., Composition and technological properties of the flour and bran from common and tartary buckwheat. Food Chem., 2003, 80, 9–15.
13. Briskin D.P., Medicinal plants and phytomedicines. Linking plant biochemistry and physiology to human health. Plant Physiol., 2000, 124, 507–514.
14. Brudzynski K., Kim L., Storage-induced chemical changes in active components of honey de-regulate its antibacterial activity. Food Chem., 2011a, 126, 1155–1163.
15. Brudzynski K., Miotto D., Honey melanoidins: Analysis of the compositions of the high molecular weight melanoidins exhibiting radical-scavenging activity. Food Chem., 2011b, 126, 1155–1163.
16. Burluc R.M., Vizireanu C., Dinica R., Dima F., The use of pseudo-cereals flours in bakery. Scientific Study and Research: Chemistry & Chemical Engineering, Biotechnology, Food Industry, 2012, 13, 177–186 (in French).
17. Chandrssekaran S., Ramanathan S., Basak T., Microwave food processing-A review. Food Res. Int., 2013, 52, 234–261.
18. Chlopicka J., Pasko P., Gorinstein S., Jedryas A., Zagrodzki P., Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. LWT – Food Sci. Technol., 2012, 46, 548–555.
19. Choy A.-L., Morrison P.D., Hughes J.G., Marriott P.J., Small D.M., Quality and antioxidant properties of instant noodles enhanced with common buckwheat flour. J. Cereal Sci., 2013, 57, 281–287.
20. Chun H.H., Song K.B., Optimisation of the combined treatments of aqueous chlorine dioxide, fumaric acid and ultraviolet-C for improving the microbial quality and maintaining sensory quality of common buckwheat sprout. Int. J. Food Sci. Tech., 2013, 49, 121–127.
21. Coda R., Di Cargno R., Gobbetti M., Rizzello C.G., Sourdough lactic acid bacteria: exploration of non-wheat cereal-based fermentation. Food Microbiol., 2014, 37, 51–58.
22. Delgado-Andrade C., Maillard reaction products: some considerations on their health effects. Clin. Chem. Lab. Med., 2014, 52, 53–60.
23. Espín J.C., García-Conesa M.T., Tomás-Barberán F.A., Nutraceuticals: Facts and fiction. Phytochemistry, 2007, 68, 2986––3008.
24. Fabjan N., Rode J., Kosir I.J., Zhang Z., Kreft I., Tartary buckwheat (*Fagopyrum tataricum* Gaertn.) as source of dietary rutin and quercetin. J. Agric. Food Chem., 2003, 51, 6452–6455.
25. Filipčev B., Šimurina O., Sakač M., Sedej I., Jovanov P., Pestorić M., Bodroža-Solarov M., Feasibility of use of buckwheat flour as an ingredient in ginger nut biscuit formulation. Food Chem., 2011, 125, 164–170.
26. Gabrovska D., Fiedlerova V., Holasova M., Maskova E., Smrcinov H., Rysova J., Winterova R., Michalova A., Hutar M., The nutritional evaluation of underutilized cereals and buckwheat. Food Nutr. Bull., 2002, 23, 246–249.
27. Gandhi A., Dey G., Fermentation responses and *in vitro* radical scavenging activities of *Fagopyrum esculentum*. Int. J. Food Sci. Nutr., 2013, 64, 53–7.
28. Gawlik-Dziki U., Dziki D., Baraniak B., Lin R., The effect of simulated digestion *in vitro* on bioactivity of wheat bread with Tartary buckwheat flavones addition. LWT-Food Sci. Technol., 2009, 42, 137–143.
29. González-Sarrías A., Larrosa M., García-Conesa M.T., Tomás--Barberán F.A., Espín J.C., Nutraceuticals for older people: facts, fictions and gaps in knowledge. Maturitas, 2013, 75, 313–34.
30. Hara T., Sasaki T., Tetsuka T., Ikoma H., Kohyama K., Effects of sprouting on texture of cooked buckwheat (*Fagopyrum esculentum* Moench) noodles. Plant Prod. Sci., 2009, 12, 492–496.
31. Haraguchi Y., Imada Y., Sawamura S.-I., Production and characterization of fine matcha for processed food. J. Jpn. Soc. Food Sci., 2003, 50, 468–473.

32. Hatcher D.W., Bellido G.G., Anderson M.J., Dexter J.E., Head D., Izydorczyk, M., Investigation of empirical and fundamental soba noodle texture parameters prepared with tartary, green testa and common buckwheat. J. Text. Stud., 2011, 42, 490–502.
33. Hatcher D.W., You S., Dexter J.E., Campbell C., Izydorczyk M.S., Evaluation of the performance of flours from cross – and self – pollinating Canadian common buckwheat (*Fagopyrum esculentum* Moench) cultivars in soba noodles. Food Chem., 2008, 107, 722–731.
34. Hayashi T., Takahashi Y., Todoriki S., Sterilization of foods with low-energy electrons ("soft-electrons"). Radiat. Phys. Chem., 1998, 52, 1–6.
35. Head D.S., Cenkowski S., Arntfield S., Henderson K., Superheated steam processing of oat groats. LWT – Food Sci. Technol., 2010, 43, 690–694.
36. Higasa S., Fujihara S., Hayashi A., Kimoto K., Aoyagi Y., Distribution of a novel angiotensin I-converting enzyme inhibitory substance (2″-hydroxynicotianamine) in the flour, plant parts, and processed products of buckwheat. Food Chem., 2011, 125, 607–613.
37. Hossen Z., Light emitting diodes increase phenolics of buckwheat (*Fagopyrum esculentum*) sprouts. J. Plant Inter., 2007, 2, 71–78.
38. Hromádková Z., Stavová A., Ebringerová A., Hirsch J., Effect of buckwheat hull hemicelluloses addition of the bread-making quality of wheat flour. J. Food Nutr. Res., 2007, 46, 158–166.
39. Juszczak L., Fortuna T., Rheology of selected Polish honeys. J. Food Eng., 2006, 75, 43–49.
40. Kalinova J., Triska J., Vrchotova N., Distribution of vitamin E, squalene, epicatechin, and rutin in common buckwheat plants (*Fagopyrum esculentum* Moench). J. Agric. Food Chem., 2006, 54, 5330–5335.
41. Kawa J. M., Taylor C. G., Przybylski R., Buckwheat concentrate reduces serum glucose in streptozotocin-diabetic rats. J. Agric. Food Chem., 2003, 51, 7287–7291.
42. Khan R. S., Grigor J., Winger R., Win A., Functional food product development – Opportunities and challenges for food manufacturers. Trends Food Sci. Technol., 2013, 30, 27–37.
43. Kim S.-J., Kim S.-K., Park C.-H., Introduction and nutritional evaluation of buckwheat sprouts as a new vegetable. Food Res. Int., 2004, 37, 319327.
44. Kowalski S., Changes of antioxidant activity and formation of 5-hydroxymethylfurfural in honey during thermal and microwave processing. Food Chem., 2013, 141, 1378–1382.
45. Kreft I., Fabjan N., Yasumoto K., Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. Food Chem., 2006, 98, 508–512.
46. Krkosková B., Mrázová Z., Prophylactic components of buckwheat. Food Res. Int., 2005, 38, 561–568.
47. Li G., Shi J., Yan M., Wang X., Effects of transglutaminase on the quality of fried instant buckwheat noodle. Trans. Chin. Soc. Agric. Eng., 2008, 24, 281–287.
48. Lin L.-Y., Liu H.-M., Yu Y.-W., Lin S.-D., Mau J.-L., Quality and antioxidant property of buckwheat enhanced wheat bread. Food Chem., 2009, 112, 987–991.
49. Liu Z., Ishikawa W., Huang X., Tomotake H., Kayashita J., Watanabe H., Kato N., A buckwheat protein product suppresses 1,2-dimethylhydrazine-induced colon carcinogenesis in rats by reducing cell proliferation. J. Nutr., 2001, 131, 1850–1853.
50. Ma Y.J., Guo X.D., Liu H., Xu B.N., Wang M., Cooking, textural, sensorial, and antioxidant properties of common and tartary buckwheat noodles. Food Sci. Biotech., 2013, 22, 153–159.
51. McKibben J., Engeseth N.J., Honey as a protective agent against lipid oxidation in ground Turkey. J. Agric. Food Chem., 2002, 50, 592–595.
52. Moroni A.V., Arendt E.K., Dal Bello F., Biodiversity of lactic acid bacteria and yeasts in spontaneously-fermented buckwheat and teff sourdoughs. Food Microbiol., 2011a, 28, 497–502.
53. Moroni A.V., Dal Bello F., Zannini E., Arendt E.K., Impact of sourdough on buckwheat flour, batter and bread: Biochemical, rheological and textural insights. J. Cereal Sci., 2011b, 54, 195–202.
54. Moroni A.V., Zannini E., Sensidoni G., Arendt E.K., Exploitation of buckwheat sourdough for the production of wheat bread. Eur. Food Res. Technol., 2012, 235, 659–668.
55. Mundo M.A., Padilla-Zakour O.I., Worobo R.W., Growth inhibition of foodborne pathogens and food spoilage organisms by select raw honeys. Int. J. Food Microbiol., 2004, 97, 1–8.
56. Nagai T., Inoue R., Kanamori N., Suzuki N., Nagashima T., Characterization of honey from different floral sources. Its functional properties and effects of honey species on storage of meat. Food Chem., 2006, 97, 256–262.
57. Nagai T., Sakai M., Inoue R., Inoue H., Suzuki N., Antioxidative activities of some commercially honeys, royal jelly, and propolis. Food Chem., 2001, 75, 237–240.
58. Normen L., Bryngelsson S., Johnsson M., Evheden L. E., Brants H., Andersson H., Dutta P., The phytosterol content of some cereal foods commonly consumed in Sweden and in the Netherlands. J. Food Compos. Anal., 2002, 15, 693–704.
59. Norton T., Sun D.-W., Recent advances in the use of high pressure as an effective processing technique in the food industry. Food Bioprocess Technol., 2008, 1, 2–34.
60. Ono K., Endo H., Yamada J., Shoji I., Isobe S., Effect of superheated steam treatment on the preservation and sensory characteristics of buckwheat noodles. J. Jpn. Soc. Food Sci., 2007, 54, 320–325.
61. Orsák M., Lachman J., Vejdová M., Pivec V., Hamouz K., Changes of selected secondary metabolites in potatoes and buckwheat caused by UV, gamma – and microwave irradiation. Rostlinna Vyroba, 2001, 47, 493–500.
62. Ötles S., Cagindi Ö., Cereals based functional foods and nutraceuticals. Acta Sci. Pol. Technol., 2006, 5, 107–112.
63. Park C.H., Kim Y.B., Choi Y.S., Heo K., Kim S.L., Lee K.C., Chang K.J., Lee H.B., Rutin content in food products processed from groats, leaves, and flowers of buckwheat. Fagopyrum, 2008, 17, 63–66.
64. Pasini F., Gardini S., Marcazzan G.L., Caboni M.F., Buckwheat honeys: screening of composition and properties. Food Chem., 2013, 141, 2802–2811.
65. Peng C.C., Chen K.C., Yang Y.L., Lin L.Y., Peng R.Y., Aquaculture improved buckwheat sprouts with more abundant precious nutrients and hypolipidemic activity. Int. J. Food Sci. Nutr., 2009, 60, 232–245.
66. Qin P., Li W., Yang Y., Guixing R., Changes in phytochemical compositions, antioxidant and a-glucosidase inhibitory activities during the processing of tartary buckwheat tea. Food Res. Int., 2013, 50, 562–567.
67. Randhir R., Kwon Y.-I., Shetty K., Effect of thermal processing on phenolics, antioxidant activity and health-relevant function-

ality of selected grain sprouts and seedlings. Innov. Food Sci. Emerg. Technol., 2008, 9, 355–364.

68. Schoenlechner R., Wendner M., Siebenhandl-Ehn S., Berghofer E., Pseudocereals as alternative sources for high folate content in staple foods. J. Cereal Sci., 2010, 52, 475–479.
69. Şensoy Í., Rosen R.T., Ho C.-T., Karwe M.V., Effect of processing on buckwheat phenolics and antioxidant activity. Food Chem., 2006, 99, 388–393.
70. Shin H.S., Ustunol Z., Influence of honey-containing marinades on heterocyclic aromatic amine formation and overall mutagenicity in fried beef steak and chicken breast. J. Food Sci., 2004, 69, FCT147-FCT153.
71. Shin H.S., Strasburg G.M., Ustunol Z., Influence of different unifloral honeys on heterocyclic aromatic amine formation and overall mutagenicity in fried ground-beef patties. J. Food Sci., 2003, 68, 810–815.
72. Skrabanja V., Liljeberg Elmstahl H.G., Kreft I., Björck I.M., Nutritional properties of starch in buckwheat products: studies *in vitro* and *in vivo*. J. Agric. Food Chem., 2001, 49, 490–496.
73. Socha R., Juszczak L., Pietrzyk S., Gałkowska D., Fortuna T., Witczak T., Phenolic profile and antioxidant properties of Polish honeys. Int. J. Food Sci. Technol., 2011, 46, 528–534.
74. Steadman K.J., Burgoon M.S., Lewis B.A., Buckwheat seed milling fraction: description, macronutrients composition and dietary fibre. J. Cereal Sci., 2001, 33, 271–278.
75. Suzuki T., Kim S.J., Mukasa Y., Morishita T., Noda T., Takigawa S., Hashimoto N., Yamauchi H., Matsuura-Endo C., Effects of lipase, lipoxygenase, peroxidase and free fatty acids on volatile compound found in boiled buckwheat noodles. J. Sci. Food Agric., 2010, 90, 1232–1237.
76. Szawara-Nowak D., Koutsidis G., Wiczkowski, W., Zieliński, H., Evaluation of the *in vitro* inhibitory effects of buckwheat enhanced wheat bread extracts on the formation of advanced glycation end-products (AGEs). LWT – Food Sci. Technol., 2014, 58, 327–334.
77. Tomotake H., Yamamoto N., Yanaka N., Ohinata H., Yamazaki R., Kayashita, J., Kato N., High protein buckwheat flour suppresses hypercholesterolemia in rats and gallstone formation in mice by hypercholesterolemic diet and body fat in rats because of its low protein digestibility. Nutrition, 2006, 22, 166–173.
78. Van Hung P., Maeda T., Tsumori R., Morita N., Characteristics of fractionated flours from whole buckwheat grain using a gradual milling system and their application for noodle making. J. Sci. Food Agric., 2007, 87, 2823–2829.
79. Vit P., Rodríguez-Malaver A., Rondón C., González I., Di Bernardo M.L., García M.Y., Bioactive indicators related to bioelements of eight unifloral honeys. Archivos Latinoamericanos de Nutrición, 2010, 60, 405–410.
80. Vogrinćić M., Timoracka M., Melichacova S., Vollmannova A., Kreft I., Degradation of rutin and polyphenols during the preparation of Tartary buckwheat bread. J. Sci. Food Agric., 2010, 58, 4883–4887.
81. Wang X.H., Gheldof N., Engeseth N.J., Effect of processing and storage on antioxidant capacity of honey. J. Food Sci., 2004, 69, 96–101.
82. Wijngaard H.H., Arendt E.K., Buckwheat. Cereal Chem., 2006, 83, 391–401.
83. Wilczyńska A., Phenolic content and antioxidant activity of different types of Polish honey – A short report. Pol. J. Food Nutr. Sci., 2010, 60, 309–313.
84. Wójtowicz A., Kolasa A., Mościcki L., Influence of buckwheat addition on physical properties, texture and sensory characteristics of extruded corn snacks. Pol. J. Food Nutr. Sci., 2013, 63, 239–244.
85. Yao Y., Shan F., Bian J., Chen F., Wang M., Ren G., D-chiro-inositol-enriched tartary buckwheat bran extracts lowers the blood glucose level in KK-Ay mice. J. Agric. Food Chem., 2008, 56, 10027–10031.
86. Yildiz G., Bilgiçli N., Effects of whole buckwheat flour on physical, chemical, and sensory properties of flat bread, lavaş. Czech J. Food Sci., 2012, 30, 534–540.
87. Yoo J., Kim Y., Yoo S.-H., Inglett G.E., Lee S., Reduction of rutin loss in buckwheat noodles and their physicochemical characterization. Food Chem., 2012, 132, 2107–2111.
88. Yoon K.H., Chung S.H., Oh H.S., Prediction of shelf-life of cold buckwheat noodles mixed with vitamin D_2 enriched siitake mushroom and seaweed derived calcium. J. Korean Soc. Food Sci. Nutr., 2007, 36, 1225–1228.
89. Zhang M., Chen H., Li J., Pei Y., Liang Y., Antioxidant properties of tartary buckwheat extracts as affected by different thermal processing methods. LWT – Food Sci. Technol., 2010, 43, 181–185.
90. Zhang Z.-L., Zhou M.-L., Tang Y., Li F.-L., Tang Y.-X., Shao J.-R., Xue W.-T., Wu Y.-M., Bioactive compounds in functional buckwheat food. Food Res. Int., 2012, 49, 389–395.
91. Zielińska D., Zieliński H., Low molecular weight antioxidants and other biologically active components of buckwheat seeds. Eur. J. Plant Sci. Biotech., 2009, 3, 29–38.
92. Zielińska D., Zieliński H., Antioxidant activity of flavone C-glucosides determined by updated analytical strategies. Food Chem., 2011, 124, 672–678.
93. Zielińska D., Szawara-Nowak D., Zieliński H., Antioxidative and anti-glycation activity of bitter buckwheat tea. Eur. J. Plant Sci. Biotech.,2009, 3, 79–83.
94. Zielińska D., Szawara-Nowak D., Zieliński H., Determination of the antioxidant activity of rutin and its contribution to the antioxidant capacity of diversified buckwheat origin material by updated analytical strategies. Pol. J. Food Nutr. Sci., 2010, 60, 315–321.
95. Zielińska D., Szawara-Nowak D., Zieliński H., Antioxidative and anti-glycation activity of buckwheat hull tea infusion. Int. J. Food Prop., 2013, 16, 228–239.
96. Zieliński H., Michalska A., Amigo-Benavente M., Del Castillo D., Piskuła, M.K., Changes in protein quality and antioxidant properties of buckwheat seeds and groats induced by roasting. J. Agric. Food Chem., 2009, 57, 4771–4776.
97. Zieliński H., Michalska A., Piskuła M.K., Kozłowska H., Antioxidants in thermally treated buckwheat groats. Mol. Nutr. Food Res., 2006, 50, 824–832.

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