Influence of Dietary Fibre Addition on the Rheological and Sensory Properties of Dough and Bakery Products

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Abstrakt

Kučerová J., Šottníková V., Nedomová Š. (2013): **Influence of dietary fibre addition on the rheological and sensory properties of dough and bakery products**. Czech J. Food Sci., **31**: 340–346.

Wheat, apple, potato, and bamboo fibres were applied at 1 and 3% content to bread wheat flour and these additions were studied for the quality of dough and bakery products characterised by farinograph parameters, laboratory baking tests, firmness, and sensory analysis. The addition of fibre caused a decrease of loaf volume, also a change of crumb colour and a slight increase of bread crumb firmness. On the other hand, the addition of fibre affected the farinograph parameters, significantly decreased the specific volume especially at 3% fibre ($P < 0.05$). A statistically significant difference ($P < 0.05$) in firmness was found out between products with added wheat and bamboo fibre. Statistically highly significant differences ($P < 0.001$) were found among the other pairs of products with fibre. The best sensory properties were detected when examining the products with an addition of wheat and potato fibre. The enrichment of bread with fibre at 1% or 3% increased the dietary fibre content in bread with slightly adverse effects on bread quality.

Keywords: wheat fibre; apple fibre; potato fibre; bamboo fibre; bakery test; sensory analysis

The definition of dietary fibre stems from the chemical compound of polysaccharide and involves all so called underused polysaccharides (cellulose, hemicellulose, and pectin), also polysaccharides used as additive substances (polysaccharides of seaweeds, microbial, plant gums and mucilages, modified polysaccharides) and lignin.

Soluble fibre is partially split by digesting enzymes in the upper gastrointestinal tract. It increases the viscosity of the stomach and intestinal content, slows down the mixing of their content, limits the access of pancreatic amylases and lipases to substrates, which also limits the absorption of nutrients by the intestinal wall. It also slows down the passage of the intestinal content and decreases the diffusion of nutrients. Mineral substances (especially ions of calcium, iron, copper, and zinc) are bound then and their accessibility is also modified. A part of the bound cation is released during the fermentation in the colon. Insoluble fibre enlarges the volume of food, shortens the period of its passage through the digestive tract and improves the intestinal peristaltic. It is metabolised along with vegetable fibre by microorganisms of the colon and appendix only. A part of fibre, especially resistant starch, is partly or fully broken into volatile oily acids with a short chain – acetic, propionic, and particularly butyric, which prevents from the quick multiplication of cancer cells of the intestinal wall. On the other hand, it does not prevent division of normal intestinal cells and supports their growth (Topping & Clifton 2001; Hollmann & Lindhauer 2004). The consumption of food with a higher content of fibre shows profitable physiological effects and health benefits, confirmed by a plenty of authors (Buttriss & Stokes 2008; Borchani *et al*. 2011). Insoluble fibre (cellulose and hemicellulose) is an effective laxative whereas soluble fibre lowers plasma cholesterol levels and helps normalise blood glucose and insulin levels, making these kinds of polysaccharides a part of dietary plans to treat cardiovascular diseases and type 2 diabetes. Dietary fibre reduces the risk of diseases which are closely associated with food including coronary heart disease, colorectal cancer, inflammatory bowel disease, breast cancer, tumour formation, mineral related abnormalities (Kumar *et al*. 2012). After the long-term excessive intake of fibre in food, in particular, combined with phytic acid, there could appear symptoms of a deficit of calcium, magnesium, iron or zinc, because insoluble polysaccharides could bind different mineral substances. Fibre can partly restrict the absorption of trace elements (McDougall *et al*. 1996).

Regarding nutrition it is recommended to increase the intake of fibre, which is deeply under the recommended daily intake in many European countries. The recommendation of the fibre volume intake is, first of all, related to age, gender and energy intake. For men with the daily energy intake 2600 kcal and women 2000 kcal, it is recommended to consume 36 g/day for men and 28 g/day for women (Anderson *et al*. 2009). Nowadays, the demand for healthily oriented products, products with a low content of sugar, low energy products and products with a high content of fibre increases. Bread, bakery and corn products are the traditional food which can be enriched with fibre. Wheat fibre is commercially used and many publications discuss the influence on bread volume and sensorical profile.

The aim of this study was to investigate the effects of various kinds of fibres and their allowances on the bread-making quality of wheat flour. The quality of baked products has been evaluated by farinograph parameters, rapid mix test, firmness and sensory analysis.

MATERIAL AND METHODS

Wheat flour and fibres. A light patent wheat fine flour (T530) ground in a commercial flour mill from the 2011 harvest was used. The granulation of flour corresponds with Decree No. 333/1997, Act No. 110/1997, effective in the Czech Republic, aperture size/throughs at least 257 μ/96% and at most 162 μ/75%. The qualitative parameters of flour were determined by standard methods: determination of moisture (%) according to ČSN ISO 712:2003, falling number(s) according to ČSN ISO 3093:2007, protein content according to Kjeldahl (%) pursuant to ČSN ISO 1871:1994, Zeleny sedimentation test [ml] according to ČSN ISO 5529:1992 and wet gluten content (%) on Glutomatic. The following kinds of fibre were used: wheat (WF 200), apple (AFE 400), potato (KF 200), bamboo (BF 300), products of the JRS Company (Rosenberg, Germany), brand name VITACEL.

Fibres of the brand name VITACEL are gluten-free, phytic acid-free and GMO-free. VITACEL® wheat fibre is white, (fine)-fibered, it contains 97% of the whole dietary fibre, of which 94.50% is insoluble fibre and 2.50% soluble fibre. VITACEL® apple fibre of reddish brown colour was obtained by drying extracted pressed pieces of cultivated apples. It has a high content of soluble dietary fibre (15%) and insoluble fibre (45%). VITACEL® potato fibre combines the positive properties of insoluble fibre with its innate starch (12%).

Potato fibre contains 70% of dietary fibre (of which soluble fibre is 6%) and binds up to 12 times more water while the risk of allergic reactions or diseases is decreased to a minimum. The addition of potato fibres increased the expansion index and led to a significant reduction in water adsorption of starch foams, generally improving foam properties (Bénézet *et al*. 2012). VITACEL® Bamboo Fibre is inert, non-caloric, and tasteless. Bamboo fibre contains 97% of dietary insoluble fibre from mature bamboo shoots. It is a white powder, not irritating, with no aroma nor odour (JRS 2012). The analysis of the chemical composition of fibre bundles showed that the components are mainly cellulose, hemicelluloses, and lignin. An increase in cellulose and hemicellulose content was detected along with a decrease in lignin content after bio-processing (Fu *et al*. 2012). Bamboo contains phytosterols and a high amount of fibre which can be labelled as nutraceuticals or natural medicines that are attracting attention from the aspect of health (Chongtham *et al.* 2011).

Farinograph parameters and Rapid Mix Test. Water absorption of flour and the other farinograph parameters (development time, stability, degree of softening) were determined when examining all the mixtures of flours and additions of fibre in a Brabender farinograph (Brabender Technologie GmbH, Co. KG, Duisburg, Germany) according to ČSN ISO 5530-1:1995. The volume of water was modified so that the maximal consistency of dough could be 500 BU.

The Rapid Mix Test (RMT) using 1000 g of light patent wheat fine flour (T530), 50 g yeast, 15 g salt, 10 g sugar, 10 g fat, and 0.02 g ascorbic acid was performed according to the Association of Cereal Research (1994). To the above-mentioned recipe was added 1% (10 g) and 3% (30 g) of wheat, apple, potato or bamboo fibre per weight of flour. The mixture was thoroughly homogenised for 5 min in an electric kneader (Zelmer Profi, Rzeszow, Poland). The content of protein was determined in the mixtures of wheat flour with fibre. After homogenising the mixture, dough was prepared by a kneader (1200 rotations per min, time of kneading 1 min). This was followed by dough resting for 20 min in a proofer (temperature 3°C and relative humidity 75%), and then remix and rest of dough for 10 minutes. Then the dough was divided (the size of dough pieces was 80 g) and moulded. After 25 min of proofing, the product was baked in a laboratory oven (ZBPP, Bydgoszcz, Poland) at 23°C for 20 min with steaming of the baking space. After cooling at laboratory temperature (21–23°C) for 2 h the loaf volume was determined by means of a rape seed displacement. Specific loaf volume (ml/100 g flour) was calculated.

Sensory analysis and firmness of baked products. A panel of ten members composed of males and females with certification in sensory evaluation was used to perform the sensory evaluation of baked goods. The sensory evaluation was assessed in six criteria (descriptors) of quality by unstructured line segments (spots 1–100). 100 spots were the best evaluation. The evaluated criteria: appearance and the shape of a product (spot 1-small, low, unsatisfactory; spot 100-large, regular, arched), colour of crust (spot 1-too dark or too light; spot 100-light brown, golden), porosity of crumb (spot 1-uneven, large cavities; spot 100-uniformly porous), elasticity of crumb (spot 1-fragile, crumbly; spot 100-smooth, flexible), aroma (spot 1-featureless; spot100-typical baked) and taste (spot 1-featureless; spot 100-pleasant baked) of a product.

The texture of bakery products can be measured by penetration test (Półtorak & Zalewska 2007). Universal testing machine TIRATEST 27025 (TIRA Maschinenbau GmbH, Schalkau, Germany) was used. The penetration depth of a cylindrical probe (diameter 6 mm) was 40 mm and cross-head speed was 20 mm/minute.

Statistical evaluation. Statistical evaluation was carried out by the method of single factor analysis ANOVA using the STATISTICA 8.0 software (StatSoft, Inc., Tulsa, USA) with the consequential examining of significance of the differences (Tukey's test). All determinations were performed in duplicates. The forms of sensory evaluation were done by measuring the distance of points on the 1–100 scale and then MS Excel was used. To monitor the relationship between the observed characteristics principal component analysis – PCA was employed by means of STATISTICA 8.0..

RESULTS AND DISCUSSION

The objective of this study was to investigate the influence of selected types of fibre on the processing parameters of dough prepared from wheat fine flour of medium quality and to evaluate the quality of bakery products. The following qualitative parameters of the examined flour were determined: falling number 260 s, N-substances 13.2%, Zeleny sedimentation test 35.6 ml, and wet gluten content 27%.

After the addition of different kinds of fibre into flour, farinograph parameters shown in Table 1 were determined. In all the tested variants water absorption was higher with 3% added fibre. There was a statistically significant difference ($P < 0.05$) between 1 and 3% added fibre. Likewise, the de-

Table 1. Effects of fibre addition on some farinograph parameters of wheat flour

Fibre (%)	Water absorption (%)	Development time (min)	Stability (min)	Degree of softening (BU)
Wheat 1	63.8	1.1	3.9	40
Wheat 3	65.1	1.2	4.3	45
Apple 1	69.2	1.5	5.2	40
Apple 3	72.3	1.7	5.9	35
Potato 1	62.1	1.9	3.8	80
Potato 3	64.3	2.2	3.6	90
Bamboo 1	66.1	1.3	4.9	45
Bamboo 3	69.4	1.5	5.0	55

Fibre – % related to the flour; BU – Brabender units; water absorption – percentage of water required to yield a dough consistency of 500 BU; development time – time to reach a maximum consistency; stability – time at which dough consistency is 500 BU; degree of softening – the difference between the maximum of the curve and the value after 12 minutes

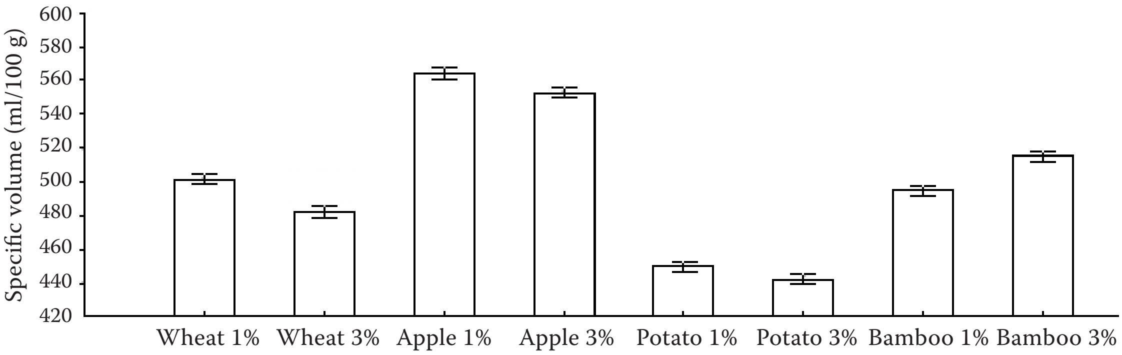

Figure 1. The effect of fiber on specific volume (vertical colums indicate the 0,95 confidence intervals)

velopment time was increased by the addition of fibre into flour, which is in accordance with the results of Almeida *et al.* (2010) and Borchani *et al.* (2011). The stability of dough to extend except flour with the addition of potato fibre and degree of softening increased by the addition of fibre except for the addition of apple fibre. Almeida *et al.* (2010) stated that when adding fibre there is a reduction of dough stability, which is confirmed in our case only when examining the apple fibre. Each kind of fibre acts in the mixture differently and unexpectedly.

Specific volume was decreased with the increasing addition of fibre (higher content of soluble fibre) when examining the variants as follows: wheat, apple, and potato fibre (Figure 1). A reduction in specific volume by fibre addition was also described in several publications (Bouaziz *et al.* 2010; Wang *et al.* 2012). Bamboo fibre does not contain any soluble fibre, unlike the other kinds of used fibre. At 3% addition a higher specific volume of bakery products was measured in our experiments by increasing the proportion of insoluble fibre. The highest specific volume of bakery products (565 ml/100 g) was detected in the mixture with 1% of apple fibre, even though water absorption of the mixture was the lowest of the observed variants (59.5%). Statistically significant differences ($P < 0.05$) were measured among all mixtures with different kinds of fibres when examining both additions (1 or 3%) of fibre.

As for the sensory evaluation of the appearance and shape of products, the products with an addition of wheat fibre were regularly formed and arched and the others with apple, potato, and bamboo fibre were comparable (Figure 2a). The samples with an addition of wheat and potato fibre had golden brown, optimally coloured crust (Figure 2b). Capuano *et al.* (2008) and Onishi *et al.* (2011) stated that the origin of brittle and golden brown crust stems from saccharose which while baking, caramelises and forms with proteins brown coloured and aromatic melanoidins in the course of the Maillard reaction. The product with the addition of apple fibre with light brown colour obtained the worst evaluation. In the evaluation of crumb elasticity and porosity the product with an addition of wheat fibre obtained the best evaluation (Figure 2c). The crumb was flexible, easily returned to the original shape and the pores were uniform. Products with the addition of bamboo fibre were evaluated almost as well as those with apple fibre. The addition of potato fibre had a negative influence on the elasticity, the product was solid and even after the test of elasticity the crumb did not want to return to the original shape.

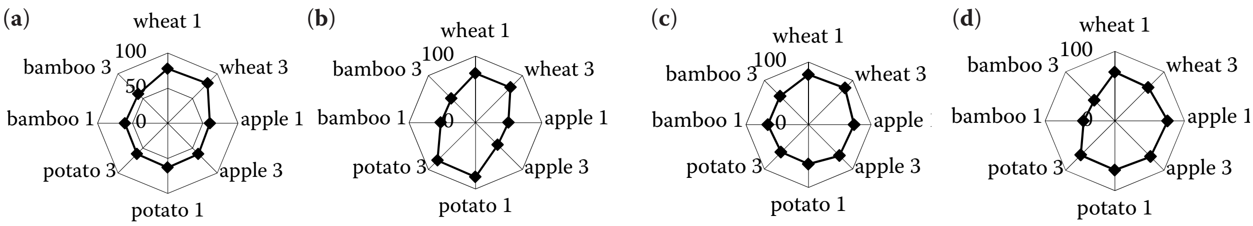

Figure 2. The effect of fiber on the selected sensory characteristics of baked products (**a**) sensory evaluation appearance and shape, (**b**) sensory evaluation of crust colour, (**c**) sensory evaluation of crumb elasticity, and (**d**) sensory evaluation of taste (in points)

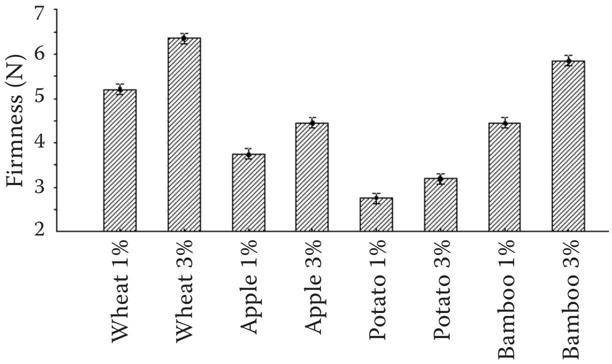

Figure 3. The firmness of products with different types and content of fiber (vertical columns indicate the 0.95 confidence intervals)

Table 2. Tukey's test – comparing the firmness of products with different kinds of fibre

Products with added fibre	Paired differences, significance
Potato – bamboo	–3.157***
Apple – bamboo	–2.233***
Wheat – bamboo	–0.469*
Apple – potato	0.923***
Wheat – potato	2.688***
Wheat – apple	1.765***

*P< 0.05; ***P < 0.001

The product with an addition of apple fibre had the significantly best aroma and taste (Figure 2d). The taste was pleasant, with the aroma of bakery products and feeling of humidity, it was also easy to swallow. The products with an addition of wheat and potato fibre were comparable, whereas the deliciousness and the ease to swallow were determined in the product with an addition of potato fibre. The sample with an addition of bamboo fibre obtained the worst evaluation. It was too dry and not easy to swallow. Since the taste of food is important not only for consumer preference, but also it is an important factor in the consumption of food, its sensory evaluation and statistical evaluation cannot therefore be excluded (Morgenstern *et al.* 2012).

Figure 3 shows the results of measuring the firmness of baked products using TIRATEST 27025. A higher percentage addition of fibre increased the firmness of all products, which was also confirmed in the study of Bouaziz *et al.* (2010). Products with the highest firmness were those with 3% addition of wheat fibre. The firmness was lower by 11% in the products with 3% addition of bamboo fibre, whereas the products with an addition of potato fibre had the consistency softer by 44% than the products with an addition of wheat fibre, which corresponds with sensory evaluation of the crumb elasticity (Figure 2c). Bread quality depends in part on the textural properties of the crumb, softness and strength being two important textural attributes (Scanlon *et al.* 2000). In Table 2 the firmness of products with different kinds of fibre determined by penetration test is compared (Tukey's test). A statistically significant difference (P < 0.05) was detected between wheat and bamboo fibre and when examining all the other pairs, a statistically highly significant difference (P < 0.001) was found out.

Principal component analysis (PCA) was used for the determination of structure and relations among the investigated characteristics describing bakery products with the addition of different kinds of fibres. The graph (Figure 4) shows a close correlation between the sensory descriptors, crust colour, flavour, aroma and specific volume of products. The smaller the angle between the characteristics, the higher their correlation.

Future perspectives

Bread contains a plenty of important nutritional components which exert a positive influence on the human health. Nevertheless, the consumption of bread has been decreasing over the last decades, which is mostly caused by factors such as change of eating habits and larger choice of replacements like breakfast cereals and fast food. Therefore, the addition of fibre into bread and wheat products is still more important. The products with wheat fibre, in comparison with conventional products with wheat bran, contain mainly cellulose and hemicellulose, little lignin, but they do not contain any identified gluten or phytic acid (Soukoulis *et al.* 2009; Chen *et al.* 2011), pesticide or residues of heavy metals. The advantage is also a possibility of shortening the length of fibres to 20 μm thanks to the special grinding process. The fibres stay suspended in the substance for a longer time and can be repeatedly stirred very well in the case of sedimentation (Bodner & Sieg 2009). Apple fibre does not contain either gluten or phytic acid. It has a relatively high content of soluble dietary fibre with thickening attributes (Bilgiçli *et al.* 2007). Bamboo fibre is now a common ingredient in breakfast cereals, fruit juices, bakery and meat

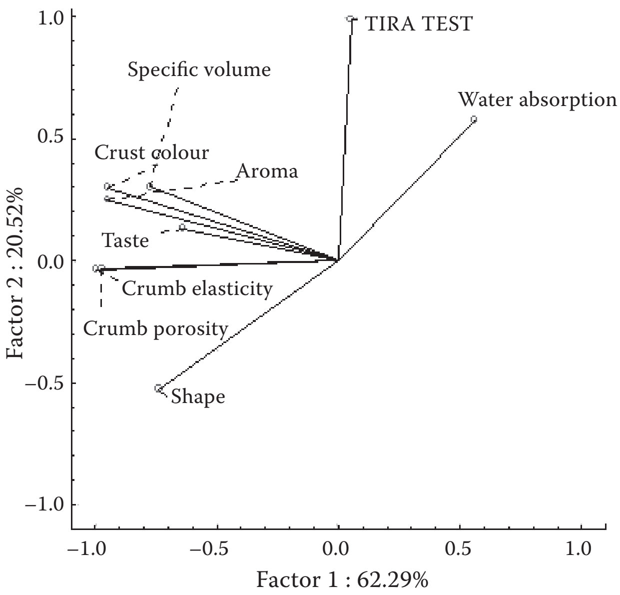

Figure 4. The projection of variables into the factor plane – PCA

products, sauces, shredded cheeses, cookies, pastas, snacks, frozen desserts, and many other food products. The health benefits of bamboo shoots and their potential for utilisation as a health food are well-known (Chongtham *et al.* 2011). These fibre-rich by-products can fortify foods, increase their dietary fibre content and result in healthy products, low in calories, cholesterol, and fat. They may also serve as functional ingredients to improve physical and structural properties of hydration, oil holding capacity, viscosity, texture, sensory characteristics, and shelf-life (Dewettinck *et al*. 2008; Elleuch *et al*. 2011; Hellyer *et al.* 2012).

Dietary fibre is widely recognised to have a beneficial role in overall health, but only at adequate levels and therefore new technologies and new products with its higher content are developed.

CONCLUSION

By the evaluation of investigated characteristics in the mixtures of flour with an addition of fibre, the highest increase of the specific volume was found when examining the apple fibre. Statistically significant differences were measured among the used mixtures with different kinds of fibres. The appearance and shape of most products with fibre addition were balanced and the products were formed and arched. Only the products with an addition of bamboo fibre were uneven as far as the shape is concerned. The addition of apple and wheat fibre had the best influence on the elasticity of the product. The crumb was flexible, easily returned to the original shape. The products with an addition of wheat and apple fibre had the significantly best taste, they also had the golden brown colour of the crust. The crumb was well done and porous. Using dietary fibre into the bakery products, their nutritional quality was increased. However, its use has an influence on the processing and quality of the final product, even though the consumers do not mind the low addition of fibre into the bakery products.

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Received for publication September 10, 2012
Accepted after corrections December 11, 2012

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