

Qualitative Properties of Pasta Enriched with Celery Root and Sugar Beet By-Products

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Abstract

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The effects of wheat flour replacement at different levels (5, 7.5, 10, and 20%) by celery root and sugar beet pulp powder on rheological parameters and quality properties of enriched pasta were studied. Sensory evaluation was also investigated. Incorporation of fibre powders increased water absorption and prolonged dough stability and dough development time. Enriched pasta had higher moisture content than control pasta. Addition of fibre powders also modified the cooking quality of pasta (cooking loss and water absorption were increased and optimal cooking time was reduced). Moreover cooked pasta with the higher addition level of celery root powder was characterised by higher intensity of vegetable taste and had pleasant flavour and colour. Sensory evaluation showed that pasta with the addition of 7.5% celery root powder was the most acceptable for assessors.

Keywords: dietary fibre; dough; pasta quality; sensory analysis

Nowadays, consumers are intended not only to satisfy their hunger and to provide their necessary nutrients but also to prevent nutrition related diseases and to improve their physical and mental well-being (ÖZYURT *et al.* 2015). Recently, many researchers have been performing studies in order to improve the technological knowledge regarding functional food as well as the development of fibre enriched food, especially cereal-based products (MIRONEASA *et al.* 2013).

Pasta is a staple food in many countries. It has an excellent nutritional profile, being a good source of complex carbohydrates and a moderate source of protein and vitamins. It is also considered an adequate vehicle for food supplementation with minerals, proteins, and many other valuable healthy components (BOROSKI *et al.* 2011). The produc-

tion of pasta enriched with vegetables is a straight forward strategy to increase the fruit and vegetable intake and this pasta can be a very good carrier of healthy compounds: dried pasta is a very good matrix to stabilize phytochemicals that otherwise, in fresh vegetables, are easily degraded during storage, transportation etc. The vegetables can be added as dry powder, fresh or partially dried pulp (OLIVIERO & FOGLIANO 2016).

A problem with the incorporation of such fibres into conventional pasta is that they can alter its sensory and cooking properties in an undesirable way. For example, whole-wheat pasta is a source of dietary fibre, but the presence of the bran and germ particles interferes with the continuity of the gluten matrix causing a decrease in firmness (DE PILLI *et al.* 2013).

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Sugar beet (*Beta vulgaris* L.) belongs to the family *Chenopodiaceae* and is mainly used for sugar production in different parts of the world (MUBARAK *et al.* 2016). Sugar beet fibre is the beet pulp remaining after water extraction of sugar from the sliced beet tuber; the isolated fibre is about 73% of the total dietary fibre (CAPPA *et al.* 2013). The main fibre types are insoluble hemicellulose and soluble pectin, but also small amounts of cellulose and lignin (AĀAR *et al.* 2016). Fibre products from sugar beets can be either the whole pulp or a purified pectic substance like arabinan and have a wide range of beneficial effects on human health (FINKENSTADT 2013). Sugar beet fibre is characterized: (1) by low phytate, which is of particular concern to nutritionists because of its possible adverse effects on mineral absorption and (2) by better water binding and retention capacity, which is of particular interest for the baking industry (FILIPOVIC *et al.* 2007). The use of sugar beet fibre in processed foods is limited by its texture and taste. It is generally used in meat patties, bakery products, cereals and assorted products that need thickening or bulking agents (FINKENSTADT 2013).

Celery (*Apium graveolens* L.) is a member of the family *Apiaceae*. The species is divided into two varieties *A. graveolens* var. *dulce* and *A. graveolens* var. *rapaceum*. The latter variety, known as ‘celeriac’, forms a large root tuber, resembling a bulb, which is cooked and eaten (SELLAMI *et al.* 2012). Celery is rich in vitamins, carotene, protein, cellulose, and other nutrients and is a good source of flavonoids, volatile oils and antioxidants. Celery can also be used in chemical and pharmaceutical industries (LI *et al.* 2017). Besides the minerals, vitamins and dietary fibre content, celeriac is in use because of its characteristic aroma and health benefits which include positive effects on lipid levels and the potential anticarcinogenic properties (ELDIN *et al.* 2011).

The purpose of this study was to evaluate rheological properties of composite flours and cooking quality of pasta enriched with celery and sugar beet pulp powder. Sensory evaluation was also investigated.

MATERIAL AND METHODS

Celery roots, semi-coarse wheat flour (wet gluten 24.67% and dry gluten 8.25%), salt and eggs were obtained from a local market. Celery root powder (CRP) preparation: celery root was washed in tap water, peeled, sliced and then the juice was extracted

with a juice extractor (Moulinex JU650). A by-product from juice extraction was dried at room temperature, milled, sieved to particle size 270–500 µm and packed in polyethylene bags. Sugar beet by-products from sugar extraction were obtained from Slovenské cukrovary, s.r.o. (Slovak Republic). Sugar beet pulp powder (SBP) preparation: sugar beet by-products were dried at room temperature, milled, sieved to particle size 270–500 µm and packed in polyethylene bags.

Proximate analysis of fibre powders contains determination of: moisture (AACC Method 44-19.01, 2000), ash (AACC Method 08-01.01, 2000), crude fat (AACC Method 30-25.01, 2000) and protein (AACC Method 46-13.01, 2000). Total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) contents were determined by an enzymatic-gravimetric method (AOAC Method 985.29-1986, 2003) using Total Dietary Fibre Assay Kit (Megazyme, Ireland). Moisture was also analysed in cooked pasta.

Rheological parameters. Rheological parameters were determined using the Brabender Farinograph (Brabender GmbH, Germany) according to the method ISO 5530-1:2013. Composite flours were prepared by substituting celery and sugar beet pulp powder at a level of 5, 7.5, 10, and 20% for semi-coarse wheat flour. Farinographic parameters were: water absorption (WA), dough stability (DS), dough development time (DDT), and mixing tolerance index (MTI).

Preparation of pasta. Pasta was prepared using a LUNA laboratory pasta machine (Häussler, Germany) according to the recipe described by HRUŠKOVÁ and VÍTOVÁ (2007). Pasta was dried at laboratory temperature (25°C) during 3 days and packed in polyethylene bags. Semi-coarse wheat flour was replaced by celery root and sugar beet pulp powder at a level of 5, 7.5, 10, and 20%.

Cooking properties. Pasta was cooked until the optimal cooking time (OCT). The cooking properties such as cooking loss (CL) and water absorption index (WAI) of pasta with addition of dietary fibre were determined according to methods described by ROSA-SIBAKOV *et al.* (2016).

Sensory evaluation. Pasta was cooked until optimal cooking time and sensory evaluation of cooked pasta was carried out using a 5-point hedonic scale by the panel of 11 trained judges according to a modified procedure reported by ABDEL-MOEMIN (2016). Evaluated descriptors were: shape, colour, flavour, grain taste, vegetable taste, granular structure, firmness, and stickiness of pasta. Overall acceptance of pasta

was evaluated using 100 mm non-structured abscissae with description of extreme points (0% – min intensity and 100% – max intensity) (KOHAJDOVÁ *et al.* 2013).

Statistical analysis. All determinations were carried out in triplicate and results were expressed as mean \pm standard deviation. Significant differences between mean values at a significance level of $P = 0.05$ were established using Student's *t*-test. Data was analysed using Statgraphics Plus, software version 3.1 (Statsoft, USA).

RESULTS AND DISCUSSION

Chemical compositions of wheat flour, CRP, and SBP are shown in Table 1. Results showed that CRP had lower protein and higher moisture, ash and fat content compared to SBP. The ash and fat contents of SBP, 3.56 and 0.42%, respectively, were in agreement with 3.84 and 0.46% described by ROSELL *et al.* (2010) in sugar beet fibre. Protein content in SBP (10.31%) was lower than that reported by ŠORONJA-SIMOVIĆ *et al.* (2016) (11.40–12.30%).

It was also observed that TDF content in CRP and SBP was very high (62.19 and 69.84%, respectively). Moreover, CRP was characterised by 48.08% IDF and 14.11% SDF and SBP contained a higher amount of IDF (49.91%) and SDF (19.93%).

The farinograph method is still the leading standard tool for assessment of the rheological behaviour of wheat flours and technological and health promoting additives during the dough development and mixing processes (MIŠ *et al.* 2017). Incorporation of fibre into wheat flour interacts directly with structural elements of the three-dimensional gluten network and disrupts the starch-gluten matrix, affecting the rheological behaviour of blended dough during mixing (MIRONEASA *et al.* 2013). Rheological properties of blended flours are shown in Table 2.

Water absorption (WA) is the amount of water required for dough to reach an arbitrarily chosen consistency; 500 Brabender unit (BU) (MIRONEASA *et al.* 2013). It follows from the results that the addition of fibre powders significantly increased WA. The highest WA values were observed at a 20% addition level of CRP (76.53%) and SBP (76.21%). Other studies also reported an increase of WA when wheat flour was replaced by carrot powder (KOHAJDOVÁ *et al.* 2012). The increase is probably due to a high number of hydroxyl groups existing in the fibre structure, which allows more water interactions through hydrogen bonding (MIRONEASA *et al.* 2013).

The greater degree of WA exhibited by fibre, in comparison with gluten proteins, can induce a dehydration phenomenon during the mixing process. It involves the migration of water from flour components, primarily gluten and starch, to fibre particles, leading to partial dehydration. A poorly hydrated gluten network becomes less elastic and more resistant to mixing (MIŠ *et al.* 2017).

The time to the nearest half-minute from the first addition of the water to the development of maximum consistency of the dough, i.e. the point immediately before the first indication of weakening, is defined as dough development time (DDT) (KUNDU *et al.* 2014). It was observed that DDT of enriched dough was prolonged by the addition level of fibre powders and ranged from 4.12 to 12.50 (5–20% CRP) and from 3.25 min to 14.50 min (5–20% SBP). The increase in DDT was attributed to the effect of the interaction between fibre and gluten that prevents the hydration of the proteins, affecting the aggregation and disaggregation of the high molecular weight proteins in wheat. However, this effect could also be related to some sort of competition for water between fibre and other flour components, which translates to a progressive dehydration of dough thus creating the impression of dough strengthening (KOHAJDOVÁ *et al.* 2013).

Dough stability (DS) is defined as the difference in time when the top of the curve first intercepts and

Table 1. Chemical composition of dietary fibre powders (%)

	Moisture	Ash	Fat	Protein	TDF	IDF	SDF
CRP	8.39 \pm 0.05	5.77 \pm 0.01	1.15 \pm 0.04	7.72 \pm 0.14	62.19 \pm 2.23	48.08 \pm 1.03	14.11 \pm 0.02
SBP	6.36 \pm 0.07	3.56 \pm 0.04	0.42 \pm 0.01	10.31 \pm 0.15	69.84 \pm 1.89	49.91 \pm 0.95	19.93 \pm 0.94
WF	8.12 \pm 0.40	0.47 \pm 0.04	1.23 \pm 0.01	10.64 \pm 0.14	2.13 \pm 0.02	nd	nd

CRP – celery root powder; IDF – insoluble dietary fibre; SBP – sugar beet pulp powder; SDF – soluble dietary fibre; TDF – total dietary fibre; WF – semi-coarse wheat flour; nd – not determined

Table 2. Rheological properties of blended flours

		Water absorption (%)	Dough development time (min)	Dough stability (min)	Mechanic tolerance index (BU)
WF		54.20 ± 0.11	2.55 ± 0.09	9.58 ± 0.14	61.00 ± 1.00
CRP	5%	60.06 ± 0.09*	4.12 ± 0.13*	11.13 ± 0.13*	50.50 ± 0.87*
	7.5%	64.03 ± 0.05*	5.03 ± 0.06*	13.40 ± 0.25*	50.67 ± 1.15*
	10%	66.14 ± 0.57*	7.22 ± 0.26*	14.67 ± 0.29*	31.33 ± 1.15*
	20%	76.53 ± 0.13*	12.50 ± 0.09*	21.50 ± 0.15*	11.00 ± 0.00*
SBP	5%	60.16 ± 0.19*	3.42 ± 0.10	12.06 ± 0.11*	60.00 ± 2.00
	7.5%	65.72 ± 0.14*	8.75 ± 0.25*	13.75 ± 0.15*	29.33 ± 1.15*
	10%	70.10 ± 1.43*	11.17 ± 0.29*	15.40 ± 0.09*	10.00 ± 0.00*
	20%	76.21 ± 1.02*	14.50 ± 0.09*	24.20 ± 0.09*	0.00 ± 0.00*

BU – Brabender unit; CRP – celery root powder; SBP – sugar beet pulp powder; WF – semi-coarse wheat flour; *significantly different from the control sample according to Student's *t*-test ($P < 0.05$)

then leaves the 500 BU line on farinography (LI *et al.* 2015). This value indicates the tolerance of flour to mixing (KUNDU *et al.* 2014). The increase of DDT and DS may be due to the delay in the hydration and development of gluten caused by the presence of fibre (RAWAT & DARAPPA 2015). A similar effect on DDT and DS was described by KUCHTOVÁ *et al.* (2016) after pumpkin powder addition.

The mixing tolerance index (MTI) indicated a difference in dough consistency between the height at the peak and the height 5 min later (LI *et al.* 2015). It is inversely proportional to the strength of the dough, higher values indicate lower strength or tolerance to mixing (RAWAT & DARAPPA 2015). From the farinographic determination it was also concluded that MTI decreased with the incorporation of fibre powders. These results could be explained by the interactions between gluten and fibre (KOHÁJDOVÁ *et al.* 2013), which strengthens the gluten fibrils probably by binding to the gluten (CHEN *et al.* 1988).

Pasta cooking is an important step in pasta processing. The cooking quality of pasta is the characteristic of greatest importance to consumers and, therefore, of greatest importance to wheat producers, breeders and processors (KALNINA & RAKCEJEVA 2015). Good pasta cooking quality is assured by the formation of a continuous and strengthened network of coagulated gluten proteins, which entraps the starch macromolecules, limiting their swelling and solubilisation into the cooking water (MARTI *et al.* 2013).

The incorporation of fibre powders affected the moisture content in pasta samples. With an increase in the fibre powder level in pasta, the moisture of pasta increased from 6.24% to 7.41% (20% CRP) and 6.53% (20% SBP).

Cooking time is an important factor for pasta quality (DE PILLI *et al.* 2013). The optimal cooking time (OCT) is the precise time at which the white core of the pasta strands disappears during cooking. A high OCT value refers to a long period of time to cook the pasta (PHONGTHAI *et al.* 2017). The addition of 20% CRP and SBP significantly reduced OCT of pasta from 6.97 min (control sample) to 4.80 min and 6.52 min, respectively. Most probably, the incorporation of vegetable flour caused a reduction in the overall proportion of gluten in the pasta. In fact, the gluten is primarily responsible for the development of the starch-protein structure, which in turn is the primary determinant of pasta texture and cooking properties (PADALINO *et al.* 2017). Similar reduction of cooking time was reported by SILVA *et al.* (2013) in pasta enriched with broccoli powder.

Cooking loss (CL) is commonly used to predict pasta cooking performance (GELENCSEŔ *et al.* 2008) and low amount of CL indicates a high quality of the cooked pasta (PHONGTHAI *et al.* 2017). Incorporation of fibre powders up to 7.5% of CRP and 10% of SBP resulted in significantly higher CL. Addition of 20% CRP increased CL more than twice (9.27%) compared with control pasta (4.50%). This increase in CL could be due to the disruption of the protein-starch matrix and the uneven distribution of water within the pasta matrix resulting from the competitive hydration tendency of the fibre (AJILA *et al.* 2010). Protein structure becomes less compact. Water penetrates the product more intensively and leaches out mainly soluble components of dry matter (SOBOTA & ZARZICKY 2013). These observations are in agreement with those reported by PADALINO *et al.* (2017) for pasta incorporated with tomato peels.

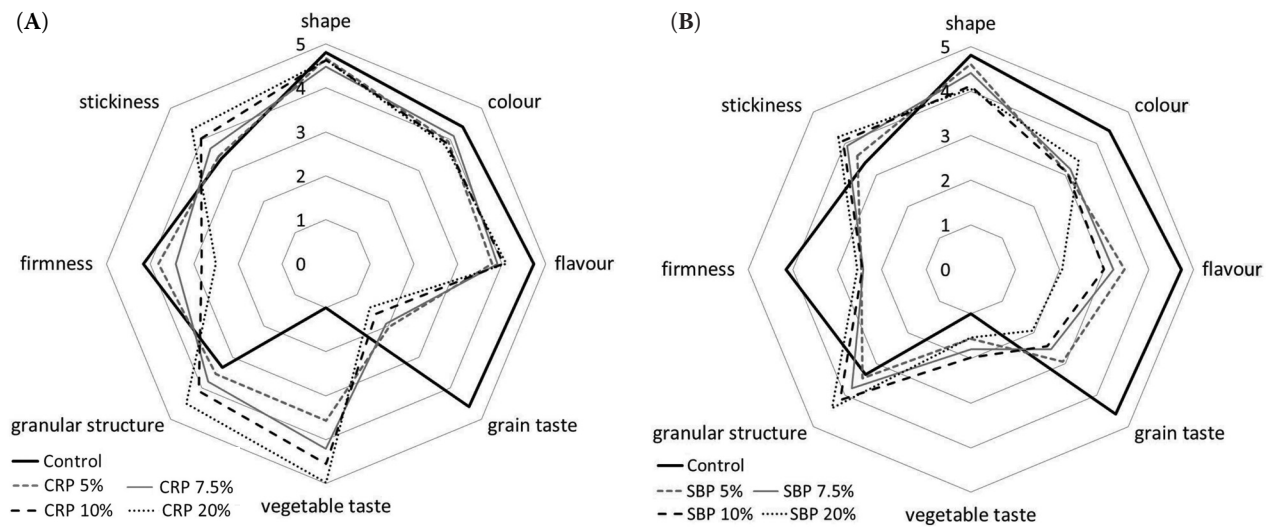


Figure 1. Sensory evaluation of pasta with addition of celery root powder (CRP) (A) and sugar beet pulp powder (SBP) (B)

Generally, the addition of fibre powders caused a significantly higher water absorption index (WAI) of pasta compared with control pasta. The highest values of WAI, 258.62 and 253.92%, were at 20% incorporation of CRP and SBP, respectively. This substantial increase in water absorption is due to an increase in fibre content of resultant pasta and strong water binding ability of fibre (KAUR *et al.* 2012). In pasta enriched with dietary fibres, the dilution of the protein network and the consequent weakening of the protein matrix are known to promote water absorption and to expose starch granules to swelling, making starch more bioavailable (OLIVIERO & FOGLIANO 2016). The product characterised by high WAI swells in stomach; thus, they are more efficient in satiating hunger and give a feeling of

satiety (SOBOTA *et al.* 2015). Similar observations were found by KAUR *et al.* (2012) and KUČTOVÁ *et al.* (2016) for pasta enriched with cereal bran and pumpkin fibre powder.

Sensory attributes of cooked pasta such as shape, colour, flavour, grain taste, vegetable taste, granular structure, firmness and stickiness are presented in Figure 1. Enrichment with CRP and SBP significantly reduced the grain taste of pasta (from 4.60 to 1.41 and 1.95, respectively). Colour is one of the most important quality properties for the acceptability of food due to its relation with product freshness and flavour expectations and therefore has a direct effect on consumers' perceptions (ÖZYURT *et al.* 2015). Pasta with the addition of CRP had brown colour similar to wholemeal pasta, while pasta with

Table 3. Effect of dietary fibre on cooking parameters of pasta

	Optimal cooking time (min)	Cooking loss (%)	Water absorption index (%)	Overall acceptance (%)	
Control	6.97 ± 0.07	4.50 ± 0.18	180.95 ± 1.54	95.40 ± 4.27	
CRP	5%	5.83 ± 0.09*	5.87 ± 0.19	72.81 ± 3.58*	
	7.5%	5.83 ± 0.07*	6.08 ± 0.04*	81.06 ± 2.21*	
	10%	5.52 ± 0.12*	6.89 ± 0.32*	75.63 ± 3.44*	
	20%	4.80 ± 0.05*	9.27 ± 0.09*	258.62 ± 2.10*	67.88 ± 3.24*
SBP	5%	6.75 ± 0.15*	4.88 ± 0.13	193.45 ± 1.73*	59.30 ± 2.67*
	7.5%	6.72 ± 0.08*	5.19 ± 0.05	205.05 ± 2.12*	45.70 ± 1.70*
	10%	6.68 ± 0.11*	5.38 ± 0.07*	221.68 ± 4.42*	38.70 ± 0.67*
	20%	6.52 ± 0.13*	8.36 ± 0.01*	253.92 ± 2.54*	25.50 ± 1.08*

CRP – celery root powder; SBP – sugar beet pulp powder; *significantly different from the control sample according to Student's *t*-test ($P < 0.05$)

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SBP had slightly greyish colour. Furthermore pasta enriched with CRP had pleasant vegetable flavour and taste which was acceptable for assessors. On the other hand, SBP pasta had a typical sugar beet flavour. The textural characteristics of cooked pasta play an essential role in determining the global acceptability of the food by consumers. A good quality pasta product should present certain degrees of firmness and elasticity, absence of stickiness, appearance uniformity and structural integrity (KALNINA & RAKCEJEVA 2015). Stickiness of pasta increased with the addition of fibre powders. Moreover enriched pasta was softer and had a more granular structure compared to control pasta.

Incorporation of fibre powders significantly affected the overall acceptance of pasta (Table 3). Generally, pasta enriched with CRP had higher values of overall acceptance at all addition levels and the highest value (81.06%) was after addition 7.5% CRP. Addition of SBP decreased the overall acceptance of pasta from 59.30% (5% addition level) to 25.50% (20% addition level).

CONCLUSIONS

In this study, the effect of celery root powder and sugar beet pulp powder addition on rheological properties of wheat dough, qualitative parameters of cooked pasta and sensory analysis was evaluated. It was found that celery root and sugar beet are a good source of total dietary fibre, most of which was insoluble. It can be concluded from the results that the incorporation of fibre powders modified farinographic parameters of wheat dough. Pasta incorporated with sugar beet pulp powder had grey colour and unsatisfactory taste. The addition of celery root powder into pasta formulation caused acceptable vegetable flavour and taste. Sensory evaluation indicated that celery roots could be incorporated into pasta up to a level of 10%.

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