doi: 10.17221/451/2015-CJFS

Influence of Chestnut Flour Addition on Quality Characteristics of Pasta Made on Extruder and Minipress

Indira KOSOVIĆ, Marko JUKIĆ, Antun JOZINOVIĆ, Đurđica AČKAR and Daliborka KOCEVA KOMLENIĆ

Faculty of Food Technology, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

Abstract

Kosović I., Jukić M., Jozinović A., Ačkar Đ., Koceva Komlenić D. (2016): **Influence of chestnut flour addition on quality characteristics of pasta made on extruder and minipress**. Czech J. Food Sci., 34: 166–172.

Durum semolina was replaced with 10, 15, and 20% of chestnut flour. Pasta was produced on a single screw extruder with the temperature profile of 80/90/90°C and on a laboratory minipress. Pasta samples were dried at room temperature and physical and sensory properties were determined. Generally, the chestnut flour addition to durum wheat pasta decreased optimum cooking time, hardness, cohesiveness, and chewiness, but increased cooking losses and pasta adhesiveness. Samples made on an extruder showed shorter optimum cooking times in relation to samples made on a minipress. Absorbed water was decreased with chestnut flour addition. Pasta made on an extruder showed a higher sensory score in comparison with pasta made on a minipress. The addition of chestnut flour influenced the colour of the samples. Samples made on an extruder showed darker colour in dried and cooked pasta samples in relation to minipress samples. In dried pasta samples, the extruder gave yellower samples in relation to the minipress, while in cooked pasta samples it was reversed. Overall, the extruder gave higher-quality pasta compared to the minipress.

Keywords: non-traditional ingredient; durum semolina; texture; pasta cooking quality

Pasta is a traditional and globally widespread cereal-based food product because of its convenience, nutritional quality, and palatability (Petitot *et al.* 2009). Durum wheat (*Triticum durum* L.) semolina is considered the best material for making high-quality pasta products due to its unique yellow colour, flavour, and cooking quality. Pasta is a good source of low glycaemic index (GI) carbohydrates, which is a result of the pasta compact nature arising from the extrusion process, and also from the formation of a tight network of gluten proteins, which entrap starch granules during the mixing and extrusion process (Gianibelli *et al.* 2005; Petitot *et al.* 2009; Bruneel *et al.* 2010; Aravind *et al.* 2012; Kuuku & Beta 2014). Gluten is very important in the formation and rheology of the dough, and it is the main determining factor of the pasta cooking quality (Sissons *et al.* 2007; Giménez *et al.* 2013). Nevertheless, pasta is not recognised as a balanced product due to the poor biological value of its proteins and the low content of dietary fibre. Nowadays, fortified food products are becoming a new trend and pasta is a good vehicle for the addition of nutrients. Incorporation of different food ingredients into pasta can increase the nutritional value of these products, but at the same time when pasta dough is fortified with other than traditional raw materials, such as cereals, it behaves differently (Chillo *et al.* 2008; Gallegos-Infante *et al.* 2010; de la Peña *et al.* 2014). Pasta cooking quality is defined by the physical competition between protein coagulation in a continuous network and starch swelling with exudate losses during cooking (Delcour *et al.* 2000; Cocci *et al.* 2008).

To the authors' knowledge, the potential of chestnut application in pasta fortification has not been examined yet. In this study we investigated supplementation of durum semolina with chestnut flour. Sweet chestnuts (*Castanea sativa* Mill.) were one of the most important food resources of the European mountain areas for many centuries (Neri *et al.* 2010). Chestnuts are made up of primarily complex carbohydrate and have a low glycaemic index and therefore

doi: 10.17221/451/2015-CJFS

are good as potential wheat flour substitutes. They are gluten free and their protein is of very high quality, comparable with eggs (Yadav *et al.* 2014). Chestnut is a good source of nutritional effective compounds such as omega-3 fatty acids, vitamins E and C and it is rich in antioxidant compounds as simple phenolics and more complex tannins. Italian chestnut flour generally presents high-quality proteins with essential amino acids (~5.8%), low amount of fat (~3.7%), and relatively high amount of dietary fibre (~10.8%) (Dall'Asta *et al.* 2013).

The first objective of this work was to examine the influence of chestnut flour addition on the quality of dried and cooked pasta samples. The second objective was to compare the quality of pasta produced on an extruder with pasta made on a laboratory minipress.

MATERIAL AND METHODS

Raw material. Durum semolina (DS) used in this study was purchased from the Gatti d.o.o. company from Zagreb (Croatia), and the chestnut flour (CF) was purchased from the Castellino di C. V. & C. snc., Villanova Mondovi, Italy.

Pasta preparation. Pasta was prepared from durum semolina and chestnut flour (10, 15, and 20% semolina replacement). Durum semolina was mixed with chestnut flour in a plastic bowl with a metal stirrer. Two mixtures were made from DS and CF. One mixture was transferred into a minipress (MPF/2.5N; Fimar, Villa Verucchio, Italy) and according to preliminary research water content of the mixture was set to 36% by adding drinking tap water (hardness app. 16.5° dH) (semolina particles were too dry with less water and could not form crumbs). The conditions applied were the following: temperature of water 25°C and kneading time 10 minutes. Dough was extruded in a laboratory minipress through a fettuccine die (8 mm, brass/bronze alloy), and air dried at room temperature for about 24 hours. Pasta made from only durum semolina (100%) was also produced and used as a reference. According to preliminary research water content of the second mixture was set to 30% (more water caused air bubbles in pasta after extrusion, due to high temperatures of the process and water evaporation) by adding drinking tap water (hardness around 16.5° dH; temperature of water was 25°C) and the mixture was left for 24 h in a refrigerator at 4°C to equilibrate in a plastic bag. The 24-h period of pre-equilibration was determined by the extruder manufacturer as time needed for water to penetrate evenly throughout the flour mass. Higher water content in the second mixture is not suitable for the production of good-quality pasta, since the mixture is too sticky for the extrusion process, while lower water content is not enough for the hydration of flour particles. After 24 h, the mixture was extruded in the laboratory single screw extruder 19/20 DN (Brabender, GmbH, Duisburg, Germany). Extrusion parameters were as follows: screw 1 : 1; flat sheet die head 25 × 1 mm; temperature profile 80/90/90°C. Extruded pasta with 25% moisture was air dried at room temperature for about 24 hours.

Pasta cooking quality. Both mixtures were analysed as follows: a 100 g sample of pasta was placed into 1000 ml of boiling tap water with 5 g of sodium chloride. According to Marti *et al.* (2010) the optimum cooking time (OCT) of pasta was evaluated as the time required for disappearance of the dry central core when gently squeezed between two glass plates (every 30 s).

The cooking loss (the amount of solid substance lost to cooking water) was determined according to the modified method by Chillo *et al.* (2008). Cooking water (100 g) was collected in a glass beaker and evaporated until a constant weight was reached. The residue was weighed and expressed as the mass of solids released during cooking. The amount of absorbed water was expressed in grams as the mass of water absorbed by 100 g cooked pasta samples. The volume increase of the pasta after cooking was determined by placing 100 g of pasta in a measuring cylinder which contained 500 ml of tap water. The amount of water that was displaced by the uncooked pasta gave the initial volume (V_i). The amount of water displaced by the cooked pasta gave the final volume (V_f). The volume increase of pasta after cooking was calculated using this equation (Sun-Waterhouse *et al.* 2013):

$$\text{Volume increase of cooked pasta (folds)} = V_f/V_i$$

where: V_f – final volume; V_i – initial volume

Colour of raw, dried, and cooked pasta was determined with a Minolta Chroma Meter (Model CR-300; Minolta Co., Osaka, Japan). The instrument was calibrated using a white tile and the colour was expressed using the CIE-Lab scale. The L^* is the measure of the brightness (lightness) from black (0) to white (100). The a^* is the function of the red-

doi: 10.17221/451/2015-CJFS

green difference – positive a^* indicates redness and negative a^* greenness. The b^* is the function of the yellow-blue difference – positive b^* indicates yellowness and negative b^* blueness. Each colour data represents the mean of five replicates.

Sensory evaluation. The evaluation was conducted according to Croatian Official Methods (1991) by a trained sensory panel. Nine panellists were selected in a preliminary session and they were experienced in the products and terminology. External shape and appearance of the dried pasta were examined visually, while its elasticity was measured by breaking a pasta sample by hands and examining the breakage surface. An amount of 50 g of dried pasta was subjected to visual examination by assessors. Samples were put on a white paper in front of the assessors. The maximum score for dried pasta properties was 20 points (maximally 5 points for external shape, 10 for appearance, and 5 for elasticity), and for cooked pasta properties (cooking loss – maximally

Table 1. Pasta cooking quality

	Minipress				Extruder			
	DS	DS+10% CF	DS+15% CF	DS+20% CF	DS	DS+10% CF	DS+15% CF	DS+20% CF
Optimal cooking time (min)*	7.3 ± 0.1^{a}	6.4 ± 0.1^{b}	5.3 ± 0.0^{c}	5.3 ± 0.1^{c}	6.2 ± 0.1^{b}	5.2 ± 0.0^{c}	5.2 ± 0.1^{c}	4.3 ± 0.1^{d}
Amount of absorbed water (g)	128.7 ± 0.5^{b}	128.1 ± 0.3^{b}	121.3 ± 1.1^{c}	136.7 ± 0.4^{a}	116.4 ± 0.8^{d}	99.9 ± 0.1^{g}	102.6 ± 0.6^{f}	104.9 ± 0.1^{e}
Cooking loss (%)	9.4 ± 0.1^{c}	7.4 ± 0.3^{e}	10.3 ± 0.1^{b}	11.5 ± 0.3^{a}	7.6 ± 0.1^{de}	6.7 ± 0.2^{f}	7.8 ± 0.1^{de}	7.9 ± 0.1^{d}
Volume of dried pasta (cm^3)	80 ± 0.0^{a}	70 ± 0.0^{b}	80 ± 0.0^{a}	80 ± 0.0^{a}	70 ± 0.0^{b}	70 ± 0.0^{b}	70 ± 0.0^{b}	80 ± 0.0^{a}
Volume of cooked pasta (cm^3)	200 ± 7.1^{bc}	240 ± 0.0^{a}	190 ± 7.1^{cd}	210 ± 7.1^{b}	190 ± 0.0^{cd}	175 ± 0.0^{e}	180 ± 7.1^{de}	180 ± 0.0^{de}
Volume increase	2.5 ± 0.1^{cd}	3.4 ± 0.0^{a}	2.4 ± 0.1^{de}	2.6 ± 0.1^{bc}	2.7 ± 0.0^{b}	2.5 ± 0.0^{cd}	2.6 ± 0.1^{bc}	2.3 ± 0.0^{e}
Sensory evaluation (points)								
External shape of dried pasta	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	4 ± 0.0^{b}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}
Appearance of dried pasta	10 ± 0.0^{a}	10 ± 0.0^{a}	10 ± 0.0^{a}	5 ± 0.0^{b}	10 ± 0.0^{a}	10 ± 0.0^{a}	10 ± 0.0^{a}	2 ± 0.0^{c}
Elasticity of dried pasta	5 ± 0.0^{a}	5 ± 0.0^{a}	3 ± 0.0^{b}	3 ± 0.0^{b}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}
Cooking loss (%)	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}	25 ± 0.0^{a}
Amount of absorbed water (g)	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}
Volume increase	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}	5 ± 0.0^{a}
Sensory evaluation**								
Odour of cooked pasta	9.7 ± 0.8^{ab}	9.7 ± 0.8^{ab}	9.7 ± 0.8^{ab}	9.4 ± 1.0^{ab}	9.7 ± 0.8^{ab}	10.0 ± 0.0^{a}	9.4 ± 1.0^{ab}	9.0 ± 1.3^{b}
Stickiness/resilience of cooked pasta	6.6 ± 1.8^{bc}	6.9 ± 1.7^{abc}	6.6 ± 1.8^{bc}	5.3 ± 2.1^{c}	8.7 ± 1.6^{a}	8.3 ± 1.6^{ab}	7.1 ± 1.5^{abc}	6.0 ± 2.8^{c}
Texture of cooked pasta	9.1 ± 1.5^{a}	7.7 ± 2.3^{ab}	7.7 ± 2.3^{ab}	6.9 ± 3.4^{b}	8.3 ± 1.6^{ab}	9.1 ± 1.5^{a}	8.7 ± 1.6^{ab}	7.9 ± 1.5^{ab}
Taste of cooked pasta	9.1 ± 1.5^{ab}	9.1 ± 1.5^{ab}	9.1 ± 1.5^{ab}	7.1 ± 1.5^{c}	9.6 ± 1.1^{a}	10.0 ± 0.0^{a}	8.9 ± 2.0^{ab}	7.6 ± 1.8^{bc}
Total score	89.5	88.4	86.1	75.7	91.3	92.4	89.1	77.5

*data are the means ± standard deviations (n = 2); **data are the means ± standard deviations (n = 9); one-way analysis of variance was performed to evaluate the statistical difference between values; means in the same row followed by different superscript letters differ significantly ($P \leq 0.05$)

doi: 10.17221/451/2015-CJFS

25 points, water uptake – maximally 10, and volume increase – maximally 5 points) the maximum score was 40 points. Odour, stickiness/resilience, texture, and taste were evaluated with the maximum score of 40 points (maximally 10 points for odour, 10 for stickiness/resilience, 10 for texture, and 10 for taste). Samples were freshly cooked to determined optimum cooking time and served on a white plate with a glass of water. The cooking quality is defined as high if pasta reaches 90–100 points, good if it reaches 80–89 points, satisfactory 70–79 points, and low below 70.

Texture profile analysis was performed on a TA.XT2 Plus texturometer (Stable Microsystems, Godalming, UK). Pasta samples were cooked (10 g of 5 cm long strands, in 100 ml tap water with 0.5 g of sodium chloride) for their previously determined optimum cooking times, drained and left to rest for 15 min (Fiorda *et al.* 2013). The texture analysis included double compression of pasta samples to 40% of their thickness with a 10 mm diameter aluminium cylindrical probe. Recording speed was 0.5 mm/s. According to Sozer *et al.* (2007), the test is a simulation of the action of jaws by compressing the bite-size piece of food twice. The resulting force-time curve is used to extract a number of textural parameters. These are primary parameters (hardness, cohesiveness, springiness, and adhesiveness) and secondary parameters (chewiness, gumminess, and resilience). Five measurements for each sample were performed.

Statistical analysis. All measurements, except the texture profile analysis and colour, were done in triplicate and data were expressed as mean ± standard deviation. The experimental data were subjected to a one-way analysis of variance (ANOVA) and Fisher's *LSD* were calculated to detect significant differences ($P \leq 0.05$) between the mean values. Statistical analyses were performed with MS Excel (MS Office 2007 Professional; Microsoft, Tulsa, USA).

RESULTS AND DISCUSSION

The cooking quality parameters of pasta samples are shown in Table 1. Control sample 1 (pasta made from durum semolina on a laboratory minipress) had the highest optimum cooking time, and OCT was decreased with CF addition to samples DS+10% CF and DS+15% CF made on a minipress and samples DS+10% CF and DS+20% CF made on an extruder. This could be due to decreased gluten content and discontinuity in the gluten network resulting in the faster moisture penetration into samples with lower protein content and therefore leading to decreased optimum cooking time. Higher-protein pasta is stronger and firmer in comparison with low-protein pasta (Aravind *et al.* 2012; Kaur *et al.* 2013). Samples made on an extruder showed shorter optimum cooking times in relation to samples made on a minipress. This could be due to higher temperatures in the extrusion process and thus starch gelatinisation. Considering cooking loss, samples made on an extruder showed lower cooking loss compared to samples made on a minipress. The addition of CF increased cooking

Table 2. Colour of pasta samples made on a minipress and an extruder

	Dried pasta			Cooked pasta		
	*L**	*a**	*b**	*L**	*a**	*b**
DS_m [A]	68.52 ± 3.15[a]	−1.24 ± 0.23[e]	18.83 ± 1.83[e]	71.99 ± 0.48[b]	−1.74 ± 0.09[e]	24.58 ± 0.35[a]
DS+10% CF_m	54.74 ± 1.93[c]	5.33 ± 0.25[c]	21.58 ± 0.54[d]	62.73 ± 0.51[c]	4.48 ± 0.2[d]	22.50 ± 0.68[b]
DS+15% CF_m	51.52 ± 2.21[cde]	4.59 ± 0.76[d]	17.30 ± 1.86[ef]	59.26 ± 0.5[d]	6.28 ± 0.27[b]	22.19 ± 0.27[b]
DS+20% CF_m	48.53 ± 1.68[ef]	4.56 ± 0.76[d]	15.51 ± 1.9[f]	56.18 ± 0.96[e]	7.61 ± 0.26[a]	20.62 ± 0.3[c]
DS_e [A]	64.65 ± 1.38[b]	−2.37 ± 0.2[f]	35.52 ± 1.13[a]	74.92 ± 0.43[a]	−3.94 ± 0.41[f]	24.18 ± 2.34[a]
DS+10% CF_e	53.42 ± 1.32[cd]	5.07 ± 0.25[cd]	30.69 ± 1.23[b]	58.36 ± 1.62[d]	4.88 ± 0.39[c]	20.41 ± 1.01[c]
DS+15% CF_e	51.48 ± 5.02[de]	7.15 ± 0.66[b]	28.42 ± 2.70[c]	55.58 ± 1.68[e]	6.45 ± 0.42[b]	19.69 ± 0.88[c]
DS+20% CF_e	46.67 ± 0.85[f]	8.37 ± 0.56[a]	26.96 ± 1.18[c]	53.28 ± 0.61[f]	7.75 ± 0.27[a]	19.29 ± 1.46[c]

[A]m – minipress; e – extruder; *L** – lightness; *a** – intensity of red (+) and green (–); *b** – intensity of yellow (+) and blue (–); data are the means ± standard deviations ($n = 5$); one-way analysis of variance was performed to evaluate the statistical difference between values; means in the same column followed by different superscript letters differ significantly ($P \leq 0.05$)

doi: 10.17221/451/2015-CJFS

loss in samples with 15 and 20% addition compared to the control sample. This increase might be due to a disrupted or weak starch-gluten network, allowing more of the gelatinised starch to leach from the pasta during cooking (Güler *et al.* 2002; Aravind *et al.* 2012). The amount of absorbed water was the highest in a sample with 20% CF made on a minipress, and the lowest in a sample with 10% CF made on an extruder. Samples made on a minipress showed higher water absorption in relation to samples made on an extruder. According to Aravind *et al.* (2012), the reduced pasta water absorption would lead to higher firmness of cooked pasta texture. Considering the total score of samples, samples made on an extruder (5–8) got more points from panellists and they showed the more acceptable sensory evaluation in relation to the respective samples made on a minipress. There was only one sample that could be defined as high-quality pasta, and it was DS+10% CF made on an extruder. Samples with 20% CF made on an extruder and on a minipress showed the lowest quality. The rest of the samples are defined as good-quality pasta.

Table 2 shows the L^*, a^*, and b^* values for the pasta samples. Both dried and cooked pasta samples made on an extruder showed darker colour in relation to samples made on a minipress. The addition of CF decreased the L^* value in dried and cooked samples. CF has slightly darker colour in relation to DS (results not shown in this work). Considering the a^* value, samples 7 and 8 made on an extruder showed higher values in relation to samples made on a minipress and for b^* values all samples made on an extruder showed higher values in relation to the minipress for dried pasta samples. Cooked pasta samples 6 and 7 made on an extruder had lower b^* values in comparison with minipress samples. According to Hidalgo *et al.* (2010) during dough extrusion in the pasta making process, carotenoids undergo through degradation. Degradation is lower when oxygen availability in the process is limited and this could be the case of samples made on an extruder.

Textural properties (hardness, cohesiveness, chewiness, and adhesiveness) of pasta samples are presented in Figure 1. Samples with 0 and 20% CF made on an extruder showed higher hardness in relation to the respective samples made on a minipress. Compared to the control sample (without CF addition), samples with 20% CF made on a minipress showed lower hardness as well as samples with 10, 15, and 20% CF addition made on an extruder. This might be due to lower gluten content in samples with the addition of CF as gluten has been reported to be responsible for the firmness of pasta. Insufficient water absorption results in pasta with hard and coarse texture, and excess water absorption results in too soft and sticky pasta, which is in correlation with the water

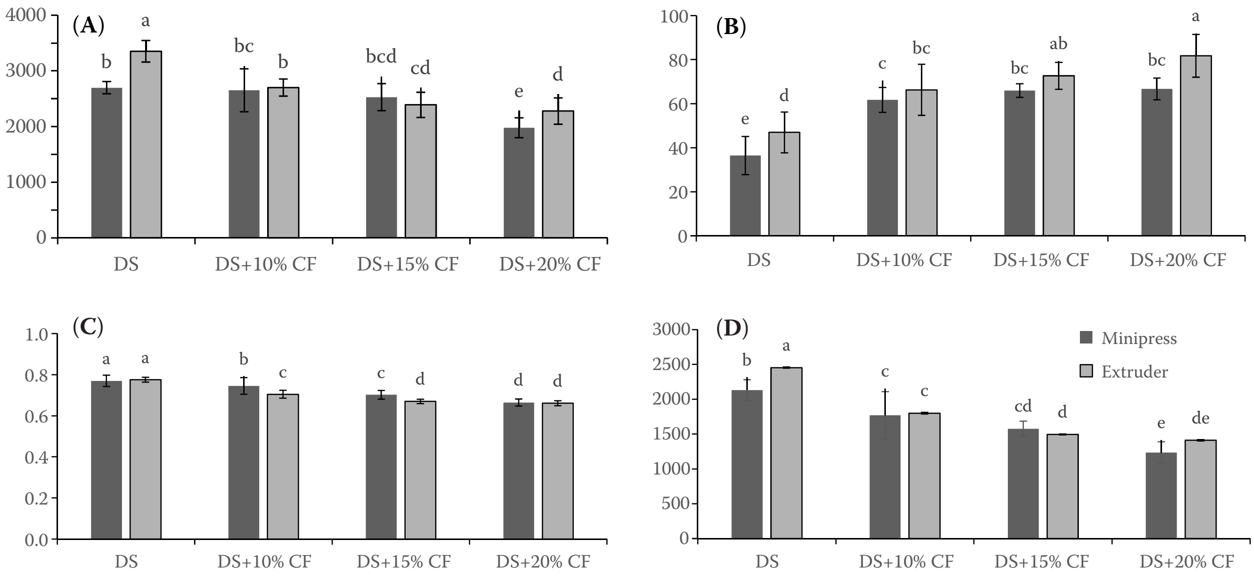

Figure 1. Textural properties of the cooked pasta samples (**A**) hardness/(g), (**B**) adhesiveness/(gs), (**C**) cohesiveness, and (**D**) chewiness

DS – durum semolina; CF – chestnut flour; data are the means ± standard deviations (n = 5); data marked with different letters are significantly different (P < 0.05) according to Fisher's least significant (*LSD*) test

doi: 10.17221/451/2015-CJFS

absorption of samples (Table 1) (Yadav *et al.* 2014). The highest hardness was observed in control sample (durum semolina) made on an extruder. Control sample made on a minipress showed similar hardness to DS+10% CF minipress and DS+10% CF extruder.

A local increase in temperature (> 60°C) due to mechanical forces can also lead to starch gelatinisation. Starch was found to be damaged to a lesser extent by sheeting than during extrusion (Zardetto & Rosa 2009), due to the lower "intrinsic stress" (lower temperatures and pressures and a shorter processing time) (Petitot *et al.* 2009). In this case, starch might be damaged to a lesser extent on a minipress than during extrusion with higher processing temperature. Cohesiveness can be a good indicator of how the sample holds together upon cooking. The cohesiveness of samples 1–6 was decreased with CF addition, which could be caused by the diluting effect of CF on gluten cohesiveness (Kordonowy & Youngs 1985). Samples 7 and 8 did not show a significant decrease with CF addition. This meant that it was more difficult for the CF-containing pasta to hold the structure together as the cooking time proceeded. Samples made on a minipress showed slightly higher cohesiveness results.

Processing conditions and CF addition showed a significant influence on the adhesiveness of samples. Results are in correlation with cooking loss of the samples, higher cooking loss is related to higher adhesiveness of the pasta. It is the leaching of amylose that mainly affects the stickiness, the more leached amylose the stickier the pasta (Haraldsson 2010).

In conclusion, chestnut flour can be successfully applied for the fortification of durum wheat pasta. Pasta with chestnut flour can be produced both on a minipress and an extruder, however, additional research is required to obtain high-quality pasta with higher proportions of chestnut flour.

References

Aravind N., Sissons M., Egan N., Fellows C. (2012): Effect of insoluble dietary fibre addition on technological, sensory, and structural properties of durum wheat spaghetti. Food Chemistry, 130: 299–309.

Bruneel C., Pareyt B., Brijs K., Delcour J.A. (2010): The impact of the protein network on the pasting and cooking properties of dry pasta products. Food Chemistry, 120: 371–378.

Chillo S., Laverse J., Falcone P.M., Protopapa A., Del Nobile M.A. (2008): Influence of the addition of buckwheat flour and durum wheat bran on spaghetti quality. Journal of Cereal Science, 47: 144–152.

Cocci E., Sacchetti G., Vallicelli M., Angioloni A., Dalla Rosa M. (2008): Spaghetti cooking by microwave oven: Cooking kinetics and product quality. Journal of Food Engineering, 85: 537–546.

Croatian Official Methods (1991): Official Methods of Cereal Analyses in Croatia. Official Gazette, Zagreb, 53: 1854–1883.

Dall'Asta C., Cirlini M., Morini E., Rinaldi M., Ganino T., Chiavaro E. (2013): Effect of chestnut flour supplementation on physico-chemical properties and volatiles in bread making. LWT-Food Science and Technology, 53: 233–239.

Delcour J.A., Vansteelandt J., Hythier M.C., Abécassis J. (2000): Fractionation and reconstitution experiments provide insight into the role of starch gelatinization and pasting properties in pasta quality. Journal of Agricultural and Food Chemistry, 48: 3774–3778.

Fiorda F.A., Soares M.S. Jr., da Silva F.A., Grosmann M.V.E. (2013): Microstructure, texture and colour of gluten-free pasta made with amaranth flour, cassava starch and cassava bagasse. LWT-Food Science and Technology, 54: 132–138.

Gallegos-Infante J.A., Rocha-Guzman N.E., Gonzales-Laredo R.F., Ochoa-Martínez L.A., Corzo N., Bello-Perez L.A., Medina-Torres L., Peralta-Alvarez L.E. (2010): Quality of spaghetti pasta containing Mexican common bean flour (*Phaseolus vulgaris* L.). Food Chemistry, 119: 1544–1549.

Gianibelli M.C., Sissons M.J., Batey I.L. (2005): Effect of source and proportion of waxy starches on pasta cooking quality. Cereal Chemistry, 82: 321–327.

Giménez M.A., González R.J., Wagner J., Torres R., Lobo M.O., Samman N.C. (2013): Effect of extrusion conditions on physicochemical and sensorial properties of corn-broad beans (*Vicia faba*) spaghetti type pasta. Food Chemistry, 136: 538–545.

Güler S., Köksel H., Ng P.K.W. (2002): Effects of industrial pasta drying temperatures on starch properties and pasta quality. Food Research International, 35: 421–427.

Haraldsson J. (2010): Development of a method for measuring pasta quality parameters. Degree project work. School of Natural Sciences, Linnaeus University. Malmö, Sweden.

Hidalgo A., Brandolini A., Pompei C. (2010): Carotenoids evolution during pasta, bread and water biscuit preparation from wheat flours. Food Chemistry, 121: 746–751.

Kaur G., Sharma S., Nag H.P.S. (2013): Enrichment of pasta with different plant proteins. Journal of Food Science and Technology, 50: 1000–1005.

doi: 10.17221/451/2015-CJFS

Kordonowy R.K., Youngs V.L. (1985): Utilization of durum bran and its effect on spaghetti. Cereal Chemistry, 62: 301–308.

Kuuku B., Beta T. (2014): Phenolic profile and carbohydrate digestibility of durum spaghetti enriched with buckwheat flour and bran. Food Science and Technology, 57: 569–579.

Marti A., Seetharaman K., Ambrogina Pagani M. (2010): Rice-based pasta: A comparison between conventional pasta-making and extrusion-cooking. Journal of Cereal Science, 52: 404–409.

Neri L., Dimitri G., Sacchetti G. (2010): Chemical composition and antioxidant activity of cured chestnuts from three sweet chestnut (*Castanea sativa* Mill.) ecotypes from Italy. Journal of Food Composition and Analysis, 23: 23–29.

Peña de la E., Manthey F.A., Patel B.K., Campanella O.H. (2014): Rheological properties of pasta dough during pasta extrusion: Effect of moisture and dough formulation. Journal of Cereal Science, 60: 346–351.

Petitot M., Abecassis J., Micard V. (2009): Structuring of pasta components during processing: Impact on starch and protein digestibility and allergenicity. A review. Trends in Food Science & Technology, 20: 521–532.

Sissons M.J., Hwee N.S., Turner M.A. (2007): Role of gluten and its components in influencing durum wheat dough properties and spaghetti cooking quality. Journal of the Science of Food and Agriculture, 87: 1874–1885.

Sozer N., Dalgiç A.C., Kaya A. (2007): Thermal, textural and cooking properties of spaghetti enriched with resistant starch. Journal of Food Engineering, 81: 476–484.

Sun-Waterhouse D., Jin D., Waterhouse G.I.N. (2013): Effect of adding elderberry juice concentrate on the quality attributes, polyphenol contents and antioxidant activity of three fibre-enriched pastas. Food Research International, 54: 781–789.

Yadav B.S., Yadav R.B., Kumari M., Khatkar B.S. (2014): Studies on suitability of wheat flour blends with sweet potato, colocasia and water chestnut flours for noodle making. Food Science and Technology, 57: 352–358.

Zardetto S., Rosa M.D. (2009): Effect of extrusion process on properties of cooked, fresh egg pasta. Journal of Food Engineering, 92: 70–77.

Received: 2015–09–24
Accepted after corrections: 2016–04–08

Corresponding author:

MSc Indira Kosović, Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, HR-31000 Osijek, Croatia; E-mail: ikosovic@ptfos.hr