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BY-PRODUCTS INGREDIENTS IN CORN BASED PASTA: EFFECTS ON THE TECHNOLOGICAL AND QUALITY CHARACTERISTICS

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Abstract

Grape peels and whey powder represent valuable by-products which contain antioxidant fibres and protein respectively that can be used to enhance gluten-free pasta nutritional and technological properties. The aim of this paper was to investigate the effect of grape peels (0, 1, 3 and 5%) or whey powder (0, 5, 10 and 15%) addition on the colour, cooking quality, microstructure, texture and sensory characteristics of gluten-free pasta based on nixtamalized corn flour. The increase of grape peels addition led to a decrease of luminosity and fracturability, higher cooking loss, cooking time and firmness, while the incorporation of whey decreased cooking loss, luminosity, fracturability and increased cooking time. The sensory profile revealed good acceptability of gluten-free pasta enriched with grape peels or whey powder, the scores depending on the addition level, the best acceptability scores being obtained for samples with the highest whey amount (15%) and with the lowest grape peels content (1%) respectively. These results revealed the possibility to develop novel corn based gluten-free pasta with higher nutritional value and acceptable technological and sensory properties by grape peels or whey incorporation.

Key words*: corn, gluten-free pasta, grape peels, valorisation, whey.*

INTRODUCTION

Nowadays the demand for gluten-free products increased among consumers suffering from celiac disease. Food industry generates significant amounts of by-products which present high biological value. Their use in food formulation has advantages from two view points: novel product nutritional value increase and environment protection though waste reduction. The main ingredients for gluten-free pasta are corn and rice flours which have relative low protein and dietary fiber contents (Bouasla et al., 2017; Giménez et al., 2013). Corn flour nutritional value can be enhanced by nixtamalization, a process which implies a thermal treatment with lime of the grains at about 90°C for 1 h (Cortés-Gómez et al., 2005). This treatment determines dough rheological properties improvement, calcium content increase and bound niacin release, but decrease fiber content by pericarp elimination (Wacher et al., 2003).

Gluten absence from pasta may cause some technological and quality issues as it has an important role on the textural characteristics of the final product (Phongthai et al., 2017). In order to minimize these negative effects, hydrocolloids and/or exogenous proteins can be used (Padalino et al., 2016). Pasta enriched with cottage cheese whey proteins presented higher nutritional value and good sensory characteristics, according to the results presented by Schoppet et al. (1976), while Marti et al. (2014) reported an improvement of pasta structure and texture after whey protein addition. Thus, whey powder which is a great source of proteins, especially albumins and globulins, vitamins and minerals (Tsakali et al., 2010) can be considered as ingredient for corn based pasta in order to enhance their nutritional and technological properties.

Gluten-free pasta fiber content can be improved by using fruits and vegetables by-products (Ciccoritti et al., 2019; Bustos et al., 2019). Grape peels are valuable by-products rich in polyphenols, fibres and minerals and were used in foods such as bread (Mironeasa et al., 2019; Deng et al., 2011), pasta (Gaita et al., 2018), pastry products (Bender et al., 2017) in order to increase the antioxidants and dietary fiber contents. Fiber-rich ingredients incorporation in pasta can negatively affect dough behaviour and final product quality (Ciccoritti et al., 2019; Mironeasa et al., 2019; Bustos et al., 2019). These effects should be minimized by finding the optimal amount of grape peels that can be added, by applying the optimization process (Mironeasa & Mironeasa, 2019).

The aim of this study was to investigate the singular effects of grape peels or whey addition in gluten-free pasta formulations based on nixtamalized corn flour. For this purpose, the raw pasta water activity, cooking quality, raw and cooked pasta colour, dough and pasta texture, microstructure, roughness and cooked pasta sensory profile were evaluated.

MATERIALS AND METHODS

Materials

Nixtamalized corn flour from white variety (Hari Masa, Mexico), whey powder (Top Ingrediente, Romania), corn starch (Sano Vita) and grape peels powder (Herbavit, Romania) were acquired from a local market of Romania and used in the experiment.

Pasta manufacturing

Proportions of 30% corn starch and 70% nixtamalized corn flour were mixed and used in pasta main recipe (C0), along with 0.50% salt and 50% water. Corn starch-flour mix was replaced by 5% (C1), 10% (C2), 15% (C3) whey powder (WP) or 1% (C4), 3% (C5), 5% (C6) grape peels powder (GP).

The ingredients were mixed for 5 min in a heavy duty mixer (Kitchen Aid, Whirlpool Corporation, USA), the dough was extruded using a short pasta accessory for the same mixer with a rigatoni mould. Pasta were dried according to the method described by Bergman et al. (1994): 30 min were kept at room temperature in open air, 60 min at 40°C, 120 min at 80°C, 120 min at 40°C in an oven, then were cooled at room temperature for 12 h and packed in polyethylene bags.

Water activity

Samples were ground using a domestic grinder and the water activity (*Aw*) was determined in triplicate with an Aqua Lab device (ICT International Amirdale, NSW 2350, Palestine) at 24.20 ± 1.28°C.

Cooking quality

Optimal cooking time

Optimal cooking time (*OCT*) was determined in triplicate according to the AACC International Approved Method 66-50.01. Five pieces of pasta were boiled in distillated water and the results were recorded when the white particles of uncooked starch disappeared after compressing the sample between two glass containers at intervals of 30 s (Espinosa-Solis et al., 2019).

Water absorption

The water absorption (*WA*) determination was achieved according to the method described by Giménez et al. (2013). Pasta sample (10 g) were boiled in 200 ml of distilled water and after *OCT* the samples were drained for 3 min and weighed, measurements being realized in triplicate.

Cooking loss

The cooking water volume resulted from the *WA* determination was measured and 30 mL were placed in glass containers and dried in an oven at 105°C until dryness (Giménez et al., 2013). After cooling, the residue was weighted. The data were collected in triplicate and the results were reported as cooking loss (*CL*) percentage of dry pasta.

Swelling index

The swelling index (*SI*) was achieved by using the method described by Piwińska et al. (2016) with some modifications. Boiled pasta used for *WA* determination were put in glass containers and dried at 105°C for 16 h, cooled and weighted. Three measurements were done and the results were expressed using the formula: $(m_1-m_2)/m_2$, where m_1 - weight of cooked pasta; m_2 - weight of pasta after drying.

Pasta colour

Colour parameters (L^* describing the lightness from black (0) to white (100), a^* expresses colour from green (−) to red (+), and b^* from blue (−) to yellow (+) nuance) of dried and cooked pasta were achieved by reflectance using a Konica Minolta CR-400 colorimeter (Tokyo, Japan). Five measurements were done for each sample.

Texture

Dough and pasta texture was evaluated by using a TVT-6700 texture analyzer (Perten Instruments, Sweden) with a 10 kg load cell.

Dough texture

Dough pieces of 50 g were tested by double compression up to 50% of the original height with a 35-mm diameter cylindrical probe, at a speed of 5.0 mm/s, a trigger force of 20 g and a recovery period between compressions of 12 s. Firmness, adhesiveness, springiness and cohesiveness were recorded in triplicate.

Dry pasta fracturability
Pasta fracturability was achieved with an aluminium break probe with a three point bend rig, set at a width of 13 mm. A single piece of sample was cut at a speed of 3 mm/s and a trigger force of 50 g. Fracturability represents the maximum force required to break the pasta, the measurements being done in triplicate.
Cooked pasta texture
Firmness, adhesiveness, stringiness and stickiness of cooked pasta were acquired by single cycle compression at 0.5 mmop (compression is specified as distance above the scale plate - mmop) with a transparent noodle probe, according to AACC 16-50 method, at a speed of 0.2 mm/s. Two pieces of sample were put on the heavy duty stand and cut with the noodle probe, three measurements being realized.

Microstructure and roughness
A Mahr CWM100 microscope (Mahr, Gottingen, Germany) from the Integrated Research, Development and Innovation Center for Advanced Materials, Nanotechnologies and Distributed Manufacturing and Control Systems (MANSiD, "Ştefan cel Mare" University of Suceava) was used in order to evaluate pasta surface microstructure and roughness, the images being registered after scanning four different areas. Mountain Map software (Digital Surf, Lavoisier, France) 8 version (trial version) was used for data processing, roughness being calculated as mean of the computed profiles of three areas.

Cooked pasta sensory evaluation
Sensory characteristics in terms of colour, taste, smell, texture, appearance and acceptability of pasta samples were evaluated in two sessions by a panel of 9 semi-trained judges. Pasta samples were boiled at *OCT* and served on white plates with 1 drop of olive oil on top of each piece. A nine-point hedonic scale was used to evaluate each characteristic.

Statistical analysis
The obtained data were processed by using the SPSS 26.0 (trial version) software for Windows (IBM, New York, USA). The differences between means were evaluated by Analysis of variance (ANOVA) and Tukey's test at 5% significance level, statistically significant differences being considered at $p < 0.05$.

RESULTS AND DISCUSSIONS

Pasta cooking quality and water activity
Pasta cooking parameters in terms of optimal time, cooking loss, water absorption and solubility index are important for final product quality. The addition of WP in pasta from nixtamalized corn flour leaded to an increase of *OCT* and decreased *WA* and *CL* compared to the control, except for C3 when *WA* was higher (Table 1). Significantly differences ($p < 0.05$) were observed for *CL*, a decreasing trend being obtained as the addition level was higher. The absence of gluten in corn pasta determines less efficient starch polymer retention in dough matrix which results in higher cooking losses (Marti et al., 2014). The addition of exogenous proteins leaded to a diminishing of cooking loss, while the *WA* was not significantly changed according to the results obtained by Marti et al. (2014). Our similar trends can be due to the protein coagulation during cooking, to their high solubility, hydration and/or emulsifying properties (Pagani et al., 1986; Marco & Rosell, 2008). Pasta containing WP presented higher A_w values compared to the control, while the swelling index presented unequal variation (Table 1).
GP addition led to an increase of *OCT*, *CL* and A_w, while *WA* and *SI* decreased as the amount was higher, statistically significant differences among samples being observed, except for *SI* (Table 1). Similar results for *WA* were reported by Bustos et al. (2019) for berry-enriched pasta, probably due to the dough network weakening by pectin (Padalino et al., 2017). The decrease of *SI* determines the same trend for *WA* as the fiber-rich ingredients compete with starch for water (Aravind et al., 2012). As compared to the control, pasta with GP presented higher cooking quality parameters values, except for *WA* and *SI* of C3 which contains the highest amount of GP. The increase of *WA* after GP addition can be related to the fiber content which has water binding capacity (Kaur et al., 2012). Cooking loss values increase can be due to the fiber interactions with dough network which may allow gelatinized starch leaching during cooking. A similar trend was reported by Aravind et al. (2012) for spaghetti enriched with insoluble dietary fiber.

Table 1. Pasta cooking quality and A_w

Sample	*OCT* (min)	*CL* (%)	*WA* (%)	*SI*	A_w
C0	5.58 ± 0.30^{ax}	10.80 ± 0.05^{bx}	234.10 ± 6.52^{ax}	0.19 ± 0.01^{abx}	0.24 ± 0.00^{ax}
C1	6.15 ± 0.12^{b}	10.72 ± 0.39^{b}	224.23 ± 1.62^{a}	0.18 ± 0.01^{a}	0.33 ± 0.01^{b}
C2	6.30 ± 0.00^{b}	9.88 ± 0.29^{ab}	231.72 ± 0.32^{a}	0.21 ± 0.00^{b}	0.44 ± 0.01^{c}
C3	6.30 ± 0.00^{b}	8.79 ± 0.49^{a}	235.50 ± 2.46^{a}	0.18 ± 0.00^{a}	0.35 ± 0.02^{b}
One way ANOVA *p* value					
	< 0.05	< 0.05	ns	< 0.05	< 0.05
C4	7.00 ± 0.00^{y}	16.76 ± 0.14^{y}	248.49 ± 4.76^{y}	0.27 ± 0.04^{x}	0.33 ± 0.02^{y}
C5	7.03 ± 0.05^{y}	16.88 ± 0.39^{y}	238.79 ± 0.79^{xy}	0.24 ± 0.06^{x}	0.33 ± 0.01^{y}
C6	7.07 ± 0.05^{y}	17.27 ± 0.05^{y}	227.82 ± 0.06^{x}	0.18 ± 0.00^{x}	0.34 ± 0.01^{y}
One way ANOVA *p* value					
	< 0.05	< 0.05	< 0.05	ns	< 0.05

Mean values with different letters in the same column are significantly different ($p < 0.05$): a-b for WP containing samples; x-y for GP containing samples C0 – control, C1 – 5% WP, C2 – 10% WP, C3 – 15% WP, C4 – 1% GP, C5 – 3% GP, C6 – 5% GP, *OCT* – optimal cooking time, *CL* – cooking loss, *WA* – water absorption, *SI* – swelling index, A_w – water activity, ns – not significant.

Colour

Pasta colour is one of the most important characteristics as it directly influences consumers purchase decision. Colour parameters of the ingredients and gluten-free pasta with WP and GP are presented in Table 2.

Table 2. Ingredients, dry and cooked pasta colour parameters

Sample	Dry pasta			Cooked pasta		
	*L**	*a**	*b**	*L**	*a**	*b**
C0	78.97 ± 0.89^{ax}	-4.25 ± 0.15^{ax}	23.20 ± 0.51^{ay}	71.16 ± 0.76^{ax}	-6.18 ± 0.07^{ax}	15.01 ± 0.58^{ax}
C1	76.78 ± 0.49^{a}	-3.96 ± 0.18^{ab}	22.69 ± 0.20^{a}	72.38 ± 0.68^{a}	-5.47 ± 0.11^{ab}	20.06 ± 0.68^{a}
C2	76.57 ± 0.20^{a}	-4.29 ± 0.28^{a}	23.97 ± 0.62a	71.15 ± 0.78^{a}	-4.56 ± 0.28^{b}	22.30 ± 0.95^{a}
C3	76.41 ± 0.15^{a}	-3.69 ± 0.25^{b}	26.73 ± 0.75^{a}	70.74 ± 0.60^{a}	-4.87 ± 0.14^{ab}	21.38 ± 0.57^{a}
One way ANOVA *p* value						
	ns	< 0.05	Ns	ns	< 0.05	Ns
C4	72.14 ± 0.40^{x}	-2.65 ± 0.13^{y}	18.13 ± 0.66^{xy}	65.78 ± 0.65^{x}	-3.43 ± 0.22^{y}	14.27 ± 0.17^{x}
C5	65.11 ± 0.86^{y}	-0.33 ± 0.11^{z}	14.46 ± 0.44^{x}	58.19 ± 0.86^{y}	-1.00 ± 0.12^{z}	9.63 ± 0.30^{y}
C6	57.47 ± 0.31^{z}	1.39 ± 0.13^{w}	12.85 ± 0.37^{x}	50.92 ± 0.94^{z}	0.77 ± 0.14^{w}	6.90 ± 0.07^{z}
One way ANOVA *p* value						
	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
WP	90.65 ± 0.11	-7.32 ± 0.08	28.04 ± 0.09	-	-	-
CSF	89.52 ± 0.06	-4.97 ± 0.01	16.48 ± 0.08	-	-	-
GP	42.61 ± 0.06	4.99 ± 0.08	6.96 ± 0.10	-	-	-

Mean values with different letters in the same column are significantly different ($p < 0.05$): a-b for WP containing samples; x-w for GP containing samples. C0 – control, C1 – 5% WP, C2 – 10% WP, C3 – 15% WP, C4 – 1% GP, C5 – 3% GP, C6 – 5% GP, L* - luminosity, a* - red-green intensity, b* - yellow-blue intensity, WP – whey protein, CSF – corn starch-flour mix, GP – grape peels, ns – not significant.

WP incorporation in nixtamalized corn pasta did not significantly affects dry and cooked pasta colour parameters ($p < 0.05$), except *a** which increased, led to a less green nuance intensity described by *a** parameter (Table 2). Phongthai et al. (2017) obtained lightness values of pasta enriched with whey protein higher than 70, which is in accordance with our findings. Control and WP containing samples presented yellow nuances, as indicated by the positive values of *b** parameter. WP addition in corn gluten-free pasta may be responsible for browning due to the Maillard reactions that can occur during drying (Manoj Kumar et al., 2019). After cooking, all colour parameters of pasta decreased, possibly due to the non enzymatic browning reactions (Marti et al., 2014).

The addition of GP led to a decrease of luminosity (*L**) and yellowness (*b**) compared to the control and with the GP increasing quantity, while the redness (*a**) increased for both dry and cooked pasta, significant differences ($p < 0.05$) being obtained among samples (Table 2). These trends could be due to the anthocyannins and tannin presence in grape peels (Fournand et al., 2006). Our results are in accordance with those reported for other fiber-rich ingredients supplementation in pasta which determined darker colors (Jayasena & Nasar-Abbas, 2012; Aravind et al., 2012; Bustos et al., 2019). Lower colour parameters values were obtained after pasta cooking, although the nuances of GP were kept after the thermal treatment, similar results being obtained by Bustos et al. (2019) for berry enriched pasta.

Texture

Dough texture

Pasta dough texture parameters are presented in Table 3. The addition of WP led to a decrease of dough firmness with the level increase, significant differences being observed ($p < 0.05$). Similar results were obtained by Asghar et al. (2009) for frozen dough with whey protein concentrates. Adhesiveness significantly ($p < 0.05$) increased as the added amount was higher. No significant changes among samples ($p > 0.05$) were obtained for springiness and cohesiveness, the most elastic dough sample being C2, while cohesiveness slightly increased with the added amount of by-products ingredients (Table 3). Compared to the control, higher firmness and adhesiveness of C1 and lower springiness were obtained, while C2 and C3 were less firm and more adhesive, elastic and cohesive than C0. Asghar et al. (2009) also reported an increase of cohesiveness values of dough when whey protein isolates were incorporated. The textural parameters variation after WP addition can be related to elastic properties of WP when it is mixed with starch and/or to the disulphide bonds that are formed (van Riemsdijk, van der Goot & Hamer, 2011).

Table 3. Pasta dough textural parameters

Sample	Firmness (g)	Adhesiveness (g · s)	Springiness (%)	Cohesiveness (adim.)
C0	2074.00 ± 45.92^{bx}	-19.28 ± 12.66^{cy}	99.76 ± 0.00^{ax}	0.17 ± 0.00^{ax}
C1	2516.00 ± 90.83^{c}	-86.4 ± 14.76^{bc}	99.66 ± 0.00^{a}	0.15 ± 0.07^{a}
C2	1938.67 ± 95.86^{b}	-185.95 ± 93.18^{b}	99.81 ± 0.00^{a}	0.17 ± 0.03^{a}
C3	1627.67 ± 17.21^{a}	-393.05 ± 67.27^{a}	99.77 ± 0.00^{a}	0.21 ± 0.01^{a}
One way ANOVA *p* value				
	< 0.05	< 0.05	ns	Ns
C4	2240.67 ± 26.85^{y}	-77.41 ± 14.80^{xy}	99.79 ± 0.00^{x}	0.15 ± 0.06^{x}
C5	2424.67 ± 15.27^{z}	-65.82 ± 27.71^{y}	99.68 ± 0.00^{x}	0.19 ± 0.00^{x}
C6	2427.00 ± 45.07^{z}	-155.46 ± 56.89^{x}	99.59 ± 0.00^{x}	0.19 ± 0.00^{x}
One way ANOVA *p* value				
	< 0.05	< 0.05	ns	Ns

Mean values with different letters in the same column are significantly different ($p < 0.05$): a-c for WP containing samples; x-z for GP containing samples C0 – control, C1 – 5% WP, C2 – 10% WP, C3 – 15% WP, C4 – 1% GP, C5 – 3% GP, C6 – 5% GP, ns – not significant.

GP incorporation in dough leaded to significantly higher firmness and adhesiveness compared to the control, an increasing trend being observed with the level increase ($p < 0.05$). GP firmer dough can be related to the limitation of water availability due to the considerable fiber content (Eskicioglu, Kamiloglu & Nilufer, 2015; Aprodu, Șerban & Banu, 2019). Higher firmness of fiber enhanced gluten-free bread dough was also reported by Sciarini et al. (2017). Springiness and cohesiveness slightly decreased after GP addition, but no significantly differences among samples were seen ($p > 0.05$).

Pasta texture

Pasta fracturability is important to be evaluated as it can predict final product behaviour during transportation and/or manipulation. Dry pasta fracturability variation with WP or GP addition level is presented in Figure 1. The increase of WP amount led to a decrease of dry pasta fracturability, the values being higher compared to the control. Gupta (2019) also revealed an increase of fracturability when pea protein flour was incorporated in gluten-free amaranth pasta, compared to the control. Similar decreasing trend was obtained for GP enriched gluten-free pasta, C6 presenting the closest value to that of the control (Figure 1). A decrease of wheat pasta fracturability with the spirulina biomass substitution level increase was also reported by Rodríguez De Marco et al. (2014) and by Jayasena and Nasar-Abbas (2014) for pasta with lupin flour. Pasta breaking strength is related to the mould type and the extrusion conditions, lower breaking stress being related to weaker internal structure which will absorb more water (Marti et al., 2011), fact supported by the WA obtained data (Table 1).

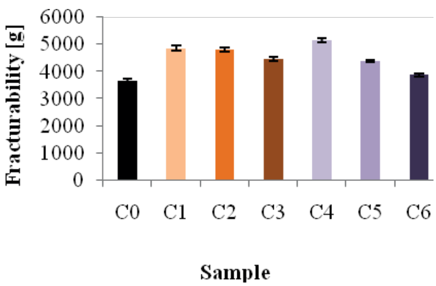

Figure 1. Gluten-free pasta fracturability: C0 - control, C1 - 5% WP, C2 - 10% WP, C3 - 15% WP, C4 - 1% GP, C5 - 3% GP, C6 - 5% GP

Textural parameters of cooked pasta play an important role in consumer's acceptability. WP addition in corn gluten-free pasta determined a decrease of cooked pasta firmness, stickiness and adhesiveness and an increase of stringiness compared to the control (Table 4). Pasta containing WP firmness did not differ significantly ($p > 0.05$) at different levels, while adhesiveness, stringiness and stickiness significantly increased ($p < 0.05$) as the addition level was higher. Stickiness values are preferred to be as lower as possible. Similar results of firmness trends were reported by Jayasena and Nasar-Abbas (2014) for pasta containing lupin flour. Gluten-free pasta dough matrix strength is given by inter- and intra molecular bonds which may disintegrate during cooking and can release extrudes during starch gelatinization which lead to pasta stickiness increase (Jayasena and Nasar-Abbas, 2014).

Table 4. Cooked pasta textural parameters

Sample	Firmness (g)	Adhesiveness (g · s)	Stringiness (mm)	Stickiness (adim.)
C0	351.33 ± 69.26^{by}	-0.36 ± 0.05^{ax}	0.08 ± 0.06^{ax}	-0.42 ± 0.06^{cy}
C1	240.33 ± 53.08^{a}	-0.16 ± 0.02^{b}	0.43 ± 0.08^{b}	-0.64 ± 0.08^{b}
C2	245.00 ± 3.61^{a}	-0.17 ± 0.11^{b}	0.70 ± 0.10^{c}	-0.73 ± 0.02^{b}
C3	242.00 ± 21.07^{a}	-0.28 ± 0.01^{ab}	0.75 ± 0.02^{c}	-0.85 ± 0.07^{a}
One way ANOVA *p* value				
	< 0.05	< 0.05	< 0.05	< 0.05
C4	243.00 ± 9.85^{x}	-0.27 ± 0.12^{x}	0.33 ± 0.05^{y}	-0.23 ± 0.01^{z}
C5	249.67 ± 11.93^{xy}	-0.03 ± 0.00^{y}	0.09 ± 0.06^{x}	-0.83 ± 0.08^{x}
C6	289.67 ± 97.21^{xy}	-0.04 ± 0.05^{y}	0.42 ± 0.04^{z}	-0.46 ± 0.09^{y}
One way ANOVA *p* value				
	< 0.05	< 0.05	< 0.05	< 0.05

Mean values with different letters in the same column are significantly different ($p < 0.05$): a-c for WP containing samples; x-z for GP containing samples C0 – control, C1 – 5% WP, C2 – 10% WP, C3 – 15% WP, C4 – 1% GP, C5 – 3% GP, C6 – 5% GP, ns – not significant.

GP incorporation led to a decrease of firmness values compared to the control (Table 4), which is in agreement with the findings of Bustos et al. (2019) for wheat pasta enriched with berries. The incorporation of GP which is a fiber rich ingredient may affect pasta dough structure resulting in a higher components losing during cooking due to the weakening effect which may lead to textural parameters decrease (Mercier et al., 2016; Bustos et al., 2019). Adhesiveness, stringiness and stickiness values of GP containing pasta increased compared to the control. Significantly differences were obtained among samples for all the textural parameters analyzed ($p < 0.05$), an increasing trend with the addition level increase being observed for firmness and adhesiveness, while stickiness decreases (Table 4). Similar trends for firmness and adhesiveness were reported by Padalino et al. (2017) for pasta enriched with tomato peels. GP containing samples stickiness decrease with the addition level increase is in agreement with the results obtained by Ciccoritti et al. (2019) for bran containing pasta.

Microstructure and roughness

Nixtamalized corn gluten-free with WP or GP pasta microstructure is presented in Figure 2.

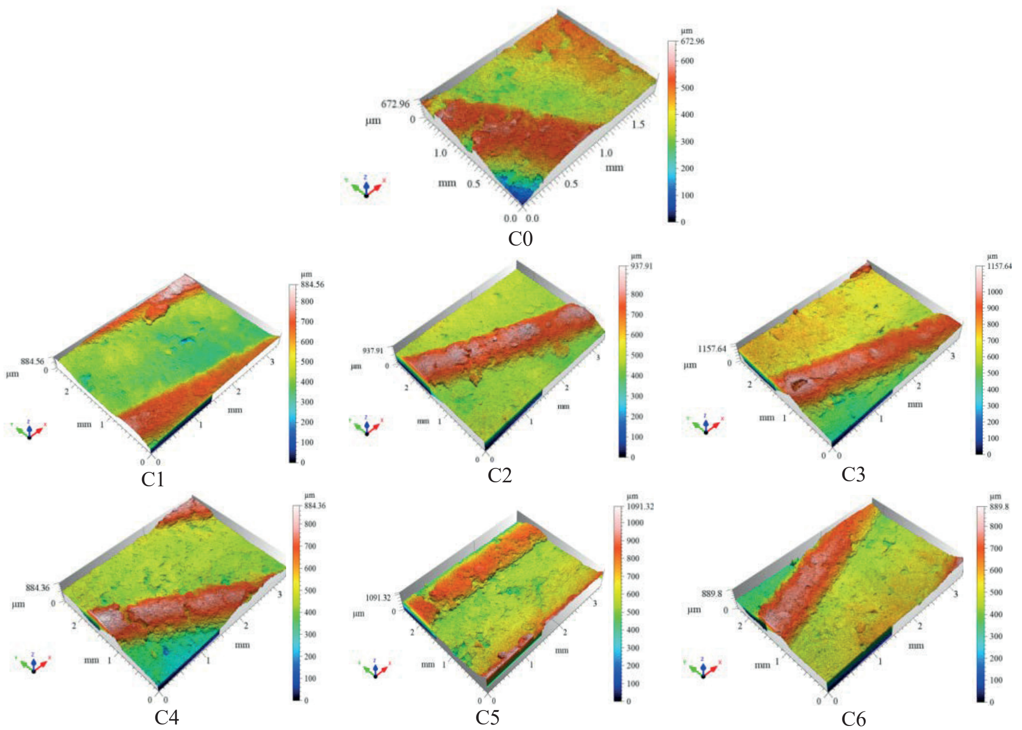

Figure 2. Gluten-free dry pasta microstructure: C0 - control, C1 - 5% WP, C2 - 10% WP, C3 - 15% WP, C4 - 1% GP, C5 - 3% GP, C6 - 5% GP

As it can be observed from Figure 2, the addition of WP led to a smoother pasta surface compared to the control. On the other hand, GP incorporation led to an increased number of holes and cracks on the surface (Figure 2) which means rougher pasta (Figure 3), this phenomena being more present in sample with highest GP amount (C6).
The presence of these cracks would allow starch, soluble dietary fiber and other solids to leach out from the matrix during boiling, leading to higher *CL* (Table 1) (Phongthai et al., 2017).
A decreasing trend of pasta roughness was obtained for all the samples containing WP (Figure 3). All WP containing samples presented lower roughness values compared to the control.
These results are in agreement with those reported by Marti et al. (2014) for gluten-free pasta enriched with whey proteins. Smoother surface can be due to the emulsifying properties of WP and to the compact structure formed with starch granules (Phongthai et al., 2017).

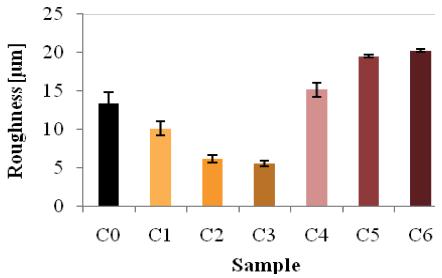

Figure 3. Gluten-free pasta roughness: C0 - control, C1 - 5% WP, C2 - 10% WP, C3 - 15% WP, C4 - 1% GP, C5 - 3% GP, C6 - 5% GP

Corn pasta with GP incorporated exhibited higher roughness values (Figure 3) which increased with the addition of by-products level increase. Surface roughness is directly influenced by the particle size as Sandberg (2015) showed that coarse bran particle size determined higher pasta roughness.
Moisture distribution within gluten-free dough matrix plays an essential role for the surface roughness as it can determine micro-cracks and uncontrolled shrinkages in the structure (D'Amico et al., 2015).
Nixtamalized corn pasta samples with WP or GP incorporation are presented in Figure 4.

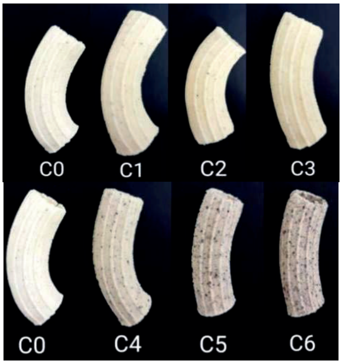

Figure 4. Gluten-free corn pasta: C0 - control, C1 - 5% WP, C2 - 10% WP, C3 - 15% WP, C4 - 1% GP, C5 - 3% GP, C6 - 5% GP

Sensory characteristics

The sensory profile of gluten-free pasta enriched with WP or GP was significantly changed compared to the control. The WP containing samples obtained higher scores for appearance, texture, taste and overall acceptability than the control samples (Figure 5). The highest scores for all the sensory characteristics studied were registered for C3, the pasta with the highest WP amount (15%). Colour and smell characteristics were appreciated with similar scores for all the samples. The yellow nuance of the pasta containing WP was preferred by consumers, as C3 sample obtained the highest scores, which is in agreement with the results presented by Jayasena et al. (2010) in the case of vegetable flours addition in pasta. Positive effects of whey powder addition on the colour, texture, flavour, taste and overall acceptability of wet noodles was also reported by Lee and Kim (2000).

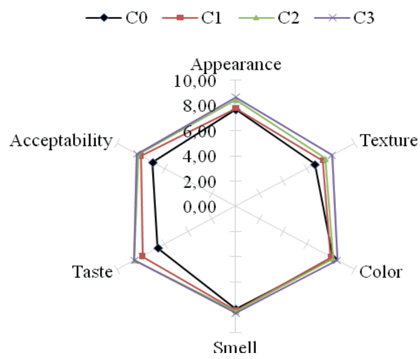

Figure 5. Sensory scores for WP pasta: C0 - control, C1 - 5% WP, C2 - 10% WP, C3 - 15% WP

GP is a fiber-rich ingredient that can negatively affect the sensory characteristics of gluten-free pasta. Sensory scores obtained for corn pasta with GP depends on the addition level used (Figure 6). The sample C4 containing the smallest amount of GP (1%) was evaluated with the highest scores for taste and overall acceptability, while in terms of colour and smell the control sample (C0) obtained the best scores.

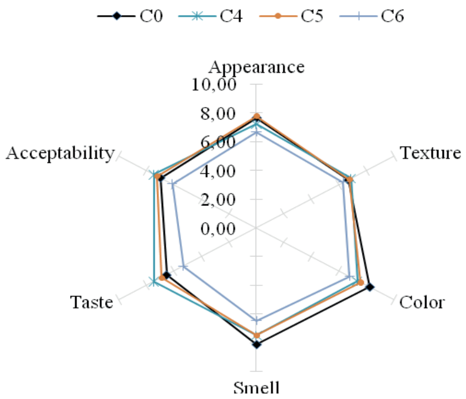

Figure 6. Sensory scores for GP pasta: C0 - control, C4 - 1% GP, C5 - 3% GP, C6 - 5% GP

The addition of 5% GP (C6) in gluten-free pasta recorder the lowest scores for all the sensory characteristics compared to the control and to the other samples (Figure 6), concluding that higher amounts than 3% of GP in corn pasta are not acceptable from sensory point of view. For high by-product addition levels the panellists noticed a gritty texture probably due to the overgrown GP particle size. The smell and the taste of the final product can be negatively influenced by the presence of polyphenols from GP (Deng et al., 2011; Gaita et al., 2018). According to the results obtained by Gaita et al. (2018), GP incorporation at levels up to 3% in wheat pasta leaded to an improvement of the sensory scores. On the other hand, cereal bran which is also a fiber rich ingredient, determined a decrease of the pasta or tortilla acceptability compared to the control (Kaur et al., 2012; Gajula et al., 2008).

CONCLUSIONS

Whey powder and grape peels are important sources of proteins and antioxidant dietary fiber respectively which make them being valuable by-products that can be used in food formulations. Whey powder addition in gluten-free pasta based on nixtamalized corn flour leaded to lower dough firmness and higher adhesiveness, roughness and fracturability of dry pasta decrease with the by-product addition level increase. In addition, the cooking quality of pasta was improved, the yellowish colour was more pronounced, cooked pasta firmness decreased while stringiness increased and better sensory characteristics were observed. Grape peels incorporation determined firmer and more adhesive dough, dry pasta fracturability decrease and roughness increase as the added amount of by-product was higher. Also a decrease of pasta cooking quality, significantly colour changes, firmer cooked pasta, and lower sensory characteristics, especially at levels higher than 3% were obtained. Thus, in order to improve the nutritional and technological characteristics of gluten-free pasta, amounts up to 10% whey powder and 1 to 3% grape peels are recommended. Our results can be useful for novel gluten-free pasta products developments in order to better satisfy consumers demand.

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