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Comparison of quality attributes of refined and whole wheat extruded pasta

María Belén Vignola, Mariela Cecilia Bustos, Gabriela Teresa Pérez*

Instituto de Ciencia y Tecnología de Alimentos Córdoba (ICYTAC-CONICET-UNC), Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, 5000, Córdoba, Argentina

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ABSTRACT

This work aimed at developing pasta with different types of flour to evaluate how different raw materials and particle size affect pasta quality. *Triticum aestivum* flour was obtained from two cultivars: Klein Guerrero and Baguette Premium 11. Grains were milled into white flour, whole-grain flour A (obtained by a cyclonic mill) and whole-grain flour B (obtained by a blade mill) to make white flour (FP), whole-grain A (WFAP) and whole-grain B (WFBP) extruded pasta. Particle size distribution and flour composition were determined in all flour samples, as were pasta cooking and nutritional properties. All types of flour showed different particle size distribution depending on composition and milling method. Both whole-grain flour pasta showed shorter optimal cooking time than FP samples due to disruptions in the gluten matrix by bran-germ particles. Cooked WFAP and WFBP samples were harder than FP samples. The highest antioxidant properties were obtained for whole-grain pasta although flour particle size did not influence protein and antioxidant contents. Even though whole-grain pasta did not show the same technological quality as that in FP, they offered a better nutritional profile due to higher protein and antioxidant levels and other healthy compounds, like fiber, found in the whole grain.

1. Introduction

Wheat grain is composed of three fractions: endosperm containing starch and proteins, germ mostly composed of lipids and proteins, and bran highly enriched in dietary fiber and minerals (Marquart, Jacobs, McIntosh, Reicks, & Poutanen, 2007). Those fractions are separated at the mill during the refining process. During this process, white wheat flour is obtained and used to manufacture wheat products while bran and germ are removed and discarded despite their high amount of vitamins, minerals (Peterson, Johnson, & Mattern, 1986), natural antioxidants (Onyeneho & Hettiarachchy, 1992) and dietary fiber (Seibel, 1996). Vitamins and minerals are crucial for a balanced diet in addition to antioxidants and dietary fiber, associated with numerous health benefits (Rosa-Sibakov, Poutanen, & Micard, 2014). Therefore, considerable attention has been paid to the production of whole-wheat flour products to face challenges met by milling and baking industries. For instance, whereas milling procedures for refined flour have been well-established, whole-grain flour is produced with a variety of techniques, resulting in a type of flour with a markedly different particle size. Particle size distribution is as an important property of cereal bran with a significant influence on the food technology (Nelson, 2001). Particle size of cereal bran influences its technological functionality due to changes in the physicochemical, water holding capacity, swelling, rheological and fat binding properties of bran (Patwa, Malcolm, Wilson, Kingsly, & Ambrose, 2014) and the release of chemical components such as bioactive compounds.

Pasta is a basic food with increasing worldwide popularity due to ease of transportation, handling, cooking and storage properties (Tudorica, Kuri, & Brennan, 2002). Durum wheat (*Triticum durum*) is the cereal chosen for pasta production because of its unique color, flavor and cooking quality (Feillet & Dexter, 1996); however, many spaghetti products are prepared from *Triticum aestivum* L. due to price and availability (Fuad & Prabhasankar, 2010). The characteristics of pasta products, such as color, cooking properties, texture and taste, are important factors affecting consumer acceptance and product quality (Lee et al., 2002).

In recent years there has been a trend towards healthy products, particularly cereal based food. Consumers are becoming increasingly health conscious and demand natural, wholesome, health promoting food. Consumption of whole-grain products, such as pasta, has been associated with reduction of risks of cardiovascular disease, type II diabetes and cancer (Liu, 2007).

Nutritionally-enriched pasta is available commercially, prepared using whole meal, semolina/flour or ground whole-wheat. It has frequently been reported that the color, cooking and sensory properties of whole-wheat or bran enriched pasta are inferior to pasta made only from semolina (Aravind, Sissons, Egan, & Fellows, 2012; Steglich, Bernin, Moldin, Topgaard, & Langton, 2015). Bran from whole grains

* Corresponding author. Av. Valparaíso S/N, Córdoba, Argentina.
E-mail address: gaperez@agro.unc.edu.ar (G.T. Pérez).

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can interfere with network formation in pasta, causing textural changes and reduced cooking quality (Manthey & Schorno, 2002). Numerous studies have focused on whole-wheat pasta made from white flour or semolina enriched with bran or germ (separately milled), which favors a homogeneous particle size (Kaur, Sharma, Nagi, & Dar, 2012; Steglich, Bernin, Moldi, Topgaard, & Langton, 2015). Yet, few studies have reported pasta made from whole-wheat flour without discarding or adding any component of grain.

The objective of this research was to develop pasta with different types of wheat flour (one white flour and two whole-grain flours from different mills) to compare pasta behavior during cooking and evaluate how flour particle size affects cooking parameters and texture. On the other hand pasta nutritional quality was evaluated in cooked pasta.

2. Materials and methods

Triticum aestivum flour was obtained from two cultivars provided by INTA (Instituto Nacional de Tecnología Agropecuaria): Klein Guerrero and Baguette Premium 11. Baguette Premium 11 belongs to group 2 that correspond to wheat varieties of good breadmaking quality used for long fermentation procedure (> 8 h) meanwhile Klein Guerrero belongs to Group 3 that correspond to wheat varieties of regular breadmaking performance (< 8 h) (RET, INASE, 2012).

Grains were milled into flour using three different mills. White refined flour (F) was obtained by milling grains with a four-roller laboratory mill (AQC 109-Agromatic AG, Laupen, Switzerland) provided with a 250 μm sieve which allowed removal of all bran content; two sets of whole-grain flour (WF) were obtained by a cyclonic mill (WFA) (Cyclotec1093, Foss, Barcelona) and by a blade mill (WFB) (Decalab, Argentina).

2.1. Particle size distribution

A ZonyTest (model EJR 2000, Spain) was used to determine the particle size distribution of the flour. Flour (100 g) was weighed and sifted on the four-stacked screens for 10 min. We used sieves with the following mesh size: 125 μm, 250 μm, 310 μm and 500 μm. After complete shaking, the material on each sieve was weighed. The weight of the sample of each sieve was then divided by total weight to calculate the percentage retained on each mesh according to AACC 55-30 method (AACC., 2000). Each sample was analyzed in duplicate.

2.2. Flour composition

Moisture, lipid, ash and wet gluten contents were determined according to approved methods 44-19, 30-10, 08-01 and 38-10 respectively (AACC., 2000). Flour protein content was determined according to approved method 30-25 (AACC., 2000). Protein content was calculated as N x 5.7. Carbohydrates were estimated by difference. All determinations were done in duplicate and expressed on dry basis.

2.3. Pasta making

All pasta samples were prepared according to Bustos, Pérez, and León (2011) with modifications. Fifty grams of flour, 500 mg of salt (NaCl) and distilled water was kneaded for 3 min to obtain homogeneous dough. The dough was shaped through the die to obtain a spaghetti form (diameter of 2.1 ± 0.2 mm) in a home pasta extruder (ATMA, Argentina). Pasta was then dried at a low temperature in two steps: the first was at 30 °C for 30 min without humidity control, in an air convection drier; the second was performed at 45 °C in a humidity-controlled (75%) drier for 17.5 h. The samples were wrapped in clean film and stored in airtight containers at room temperature until needed.

2.4. Pasta cooking properties

Optimal cooking time (OCT) was determined according to method 16–50 (AACC., 2000). After cooking and draining, samples were analyzed for Water absorption (WA), Swelling Index (SI), Cooking loss (CL) according to Tudorica et al. (2002). All determinations were done in duplicate.

2.5. Cooked pasta textural analysis

A texture analyzer (Universal Testing machine, INSTRON 3342, USA) with a load cell of 500 N equipped with a Windows version of the Texture Expert Software package was used to make texture analysis; the parameters determined were pasta hardness, cohesiveness and chewiness. All samples were cooked on the day of determination. Before testing the samples, excess water was blotted with an absorbent paper. A cylindrical probe (similar to HDP/PFS) compressed the samples (4 strands 5 cm long each) at a rate of 2.0 mm/s to 70% strain. The probe was retracted and followed by a second compression cycle after 2 s. The test was repeated on 2 sets of each type of pasta.

2.6. Color of cooked pasta

The color of cooked pasta was determined with a Minolta 508 d spectrophotometer (Ramsey, NJ, USA). Eight-millimetre measurement apertures, D65 illuminant, 10° angle of observer were set, according to approved methods 14–22 (AACC., 2000). At least eight readings were taken from the cooked pasta strand and recorded as CIE-LAB, L* (lightness), a* (redness-greenness) and b* (yellowness-blueness) values (Joshi & Brimelow, 2002).

2.7. Nutritional attributes of cooked pasta

2.7.1. Extraction method for antioxidant determination

The total polyphenol content, ferric reducing activity and radical scavenging activity was measured in extracts from freeze-dried uncooked and cooked pasta. The mixture of methanol/acetone/water (30:30:40 v/v) was used by adding 1 mL to 200 mg of sample; agitation in vortex was applied for 5 min; and the mixture was then centrifuged 10 min at 10,000 g, supernatant collected and extraction repeated. Finally, both supernatants were combined and kept in dark at −20 °C. Duplicate extractions were performed in each sample and all determinations were done in triplicate.

2.7.2. Total polyphenol content

Total polyphenols content was determined by the Folin-Ciocalteu method, using gallic acid as a calibration standard (Prior, Wu, & Schaich, 2005). The results were expressed as mg of gallic acid equivalents (GAE) per gram of uncooked/cooked dried weight (DW) pasta.

2.7.3. Radical scavenging activity

Radical scavenging activity was measured by the ABTS method according to Re et al. (1999). Trolox (Sigma 238813) was used as a standard. A bi-exponential fit was applied using ORIGIN 8.0 software (Origin-Lab Corporation, Northampton, MA, USA). Results were expressed as μmol trolox equivalent per gram of uncooked/cooked DW pasta.

2.7.4. Ferric reducing ability

Ferric reducing ability of pasta extracts was determined by the FRAP assay according to Pulido, Bravo, and Saura-Calixto (2000) using Trolox as a standard. Results were expressed as μmol trolox equivalent per gram of uncooked/cooked pasta DW.

2.7.5. Total dietary fiber

Cooked pasta (1 g) was dried at 100 °C overnight and milled for total dietary fiber content determination according to method 32-05 (AACC., 2000). Two replicates were analyzed. Results were expressed as the percentage of total dietary fiber in dry basis.

2.7.6. Starch analysis and protein content

Resistant and total starch was measured on OCT cooked pasta according to AACC 32–40.01 (AACC., 2000). Protein content of cooked pasta was determined by micro Kjeldahl method modified with boric acid (approved method 30-25, AACC., 2000). Protein was calculated as N x 5.7 and determined in duplicate.

2.8. Statistical analysis

Statistical analyses were performed using Infostat/Professional statistical software (Di Rienzo, Casanoves, Balzarini, Gonzalez, Tablada, Robledo, InfoStat versi, ó, & n, 2012). Data were examined by ANOVA and results were compared by Fisher's test at a significance level of 0.05. The differences among genotypes and between flour or pasta types were analyzed and the results were expressed as the mean of two repetitions. Two or three replications were carried out depending on the determination.

3. Results and discussion

3.1. Particle-size distribution

All types of flour showed very different particle size distribution depending on composition and milling method (Fig. 1). White flour (F) contains a considerably higher amount of particles (approximately 80%) in the small size region (≤125 μm) than whole-grain flour (WF). Similar results were found by Hareland (1994) and Manthey and Schorno (2002). Both whole-grain type of flours presented different particle size distribution as shown in Fig. 1. Regarding WFA, 58% of particles were equal to or smaller than 125 μm, 33% were compressed between 210 μm and 350 μm and only 9% were equal to or bigger than 500 μm. On the other hand, WFB presented 27% of particles equal to or smaller than 125 μm, 30% between 210 μm and 350 μm and 42% equal to or bigger than 500 μm. No significant differences were observed between wheat genotypes indicating that milling technique generated the differences between the types of flour.

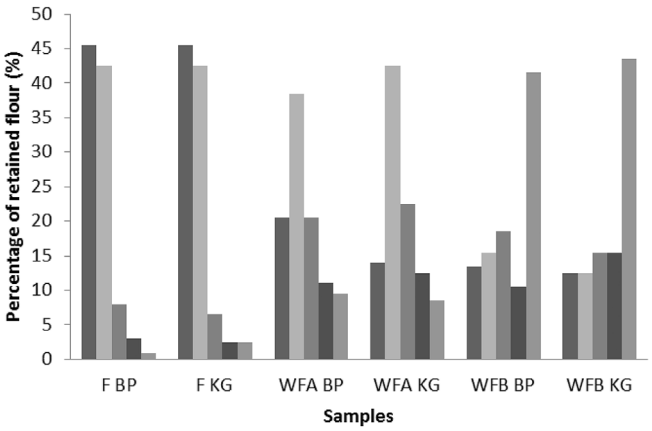

Fig. 1. Particle size distribution of white flour (F), and whole-grain flours milled by cyclonic mill (WFA) and blade mill (WFB) from Baguette Premium 11 (BP) and Klein Guerrero (KG) wheat genotypes in each sieve size mesh (μm). ■<125 ■125 - 209 ■210-349 ■350-499 ■>500

3.2. Flour composition

Table 1 shows moisture, ash, protein, lipids, carbohydrates and wet gluten values of each type of flour (WF, WFA and WFB) from two cultivars: Klein Guerrero and Baguette Premium 11. Whole-grain flour protein content varied from 11.24 g/100 g–15.15 g/100 g. Similar protein values were found by Liu et al. (2015). Klein Guerrero reported the highest protein content in all analyzed flour. However, no significant differences were found between the three different types of flour. These results agree with those reported by Hatcher, Anderson, Desjardins, Edwards, and Dexter (2002) who found that differences on milling procedure used to produce a varying particle size of the flour did not affect protein content. As expected, ash and lipid content was higher in whole-grain flour than in white flour, as described by Liu et al. (2015). However, no significant differences were found between both whole-grain types of flour. The bran layer is rich in ash (Pomeranz, 1988); hence removing bran during milling would lower ash content in white flour. Carbohydrate content was higher in F than in whole-grain flour as reported by Kaur et al. (2012). Wet gluten percentage was higher in F because of the dilution effect of bran on whole-grain flour. In addition, the presence of large bran-type particles can disintegrate the forming gluten matrix to a greater degree and interfere with the uniform hydration of the material, thus inhibiting the formation of the gluten matrix. These results agreed with those found by Sobota, Rzedzocki, Zarzycki, and Kuzawinska (2015) who studied gluten content in semolina and whole-grain durum wheat flour.

3.3. Pasta cooking parameters

Table 2 summarizes the results of cooking properties for pasta samples made from white flour (FP), whole-grain A flour (WFAP) and whole-grain B flour (WFBP). The optimal cooking time (OCT) varied from 13 to 18 min. Both whole-grain pasta samples showed shorter OCT than that found in FP. These results agree with those reported by many authors (Chillo, Laverse, Falcone, Protopapa, & Del Nobile, 2008; Kaur et al., 2012) who compared pasta with durum semolina and pasta with added bran. The shorter cooking time for whole-grain flour pasta has been associated with the physical disruption of the gluten matrix by the bran and germ particles which provided a path of water absorption into the whole-wheat spaghetti strand that reduced cooking time (Kaur et al., 2012; Manthey & Schorno, 2002). FP made from Baguette Premium 11 showed the highest OCT while WFAP made from Klein Guerrero presented a higher OCT than that found in Baguette Premium 11 (Table 2).

Water absorption values were within the range of 118.7–150.6% (Table 2). The highest water absorption values were observed in FP which presented a uniform distribution of small particle sizes, promoting a well-developed protein-starch matrix that leads to high quality pasta which retains more water. Only WFAP absorbed less water than FP and WFBP, as also shown by Aravind et al. (2012) who concluded that water absorption decreases while increasing bran and germ content. WFAP presented higher quantity of intermediate size particles than that found in WFBP and these particles seem to interfere more with gluten network leading to less water absorption. Fiber and lipid content could also be related to decreased water absorption (Sozer, Dalgiç, & Kaya, 2007). Ramy, Salama, and Shouk (2002) also found decreased water absorption and increased cooking loss in pasta with 20–40 g/100 g bran and germ content. The variation in water uptake was directly related to OCT. In addition, in FP sample, the genotype Baguette Premium 11 displayed higher values than those shown in Klein Guerrero ($p < 0.05$). For whole-grain flour pasta no differences in genotypes were observed for water absorption values (Table 2).

Swelling index (SI) varied from 1.6 to 2.1% (Table 2). According to our results, Kaur et al. (2012) also showed that SI decreased as more bran and germ were included in the pasta. For this parameter, genotypes exhibited the same behavior as that in water absorption

Table 1
Moisture, ash, protein, lipids, carbohydrates and wet gluten (WG) content of white flour (F), whole-grain flour A (WFA) and whole-grain flour B (WFB) from two wheat genotypes.[a,b]

Sample	Genotype	Moisture	Ash	Protein	Lipid	Carbohydrate	WG
F	KG	10.90 ± 0.14 aA	0.55 ± 0.00 aA	14.29 ± 0.12bA	1.07 ± 0.14 aA	83.95 ± 0.25 aB	34.57 ± 0.25bB
	BP 11	10.84 ± 0.11bA	0.55 ± 0.00 aA	11.24 ± 0.12 aA	1.35 ± 0.20 aA	86.85 ± 0.08bB	27.15 ± 0.10 aB
WFA	KG	11.16 ± 0.40 aA	1.72 ± 0.00bB	15.15 ± 0.23bA	2.65 ± 0.03bB	79.60 ± 0.20 aA	24.87 ± 0.30bA
	BP 11	10.80 ± 0.23 aA	1.54 ± 0.00 aB	12.69 ± 0.04 aA	1.52 ± 0.25 aB	84.33 ± 0.21bA	21.31 ± 0.35 aA
WFB	KG	11.35 ± 0.06 aA	1.64 ± 0.02 aB	14.96 ± 0.05bA	2.12 ± 0.10 aB	81.26 ± 0.06 aA	19.96 ± 0.24 aA
	BP 11	11.66 ± 0.91 aA	1.59 ± 0.00 aB	12.85 ± 0.14 aA	1.76 ± 0.23 aB	83.87 ± 0.91 aA	21.89 ± 0.18bA

[a] The data are the means of two independent experiments ± standard deviations (n = 2).
[b] KG: Klein Guerrero, BP 11: Baguette Premium 11. Different capital letters within the same column represent significant flour differences (P ≤ 0.05) while different lowercase letters within the same column represent significant genotype differences in each type of flour (P ≤ 0.05).

determination.

Cooking loss is one of the most important parameters that affect consumer acceptance in pasta products (Sissons, Egan, & Gianibelli, 2005; Fu, 2008). Thus, it is frequently used as a predictor of the overall cooking performance of pasta. Cooking loss, analyzed as weight of total solids lost during cooking, varied from 5.5 to 6.4%, which is within the expected limits (7–8%) for pasta made from durum wheat (Dick & Youngs, 1988). The small cooking loss found in our samples is remarkable as a good quality indicator since different authors (Kaur et al., 2012; West, Duizer, & Seetharaman, 2013) found higher values in whole-grain pasta. No significant differences were found in the three types of pasta analyzed and in both cultivars (Table 2). However, we observed a tendency to increase cooking loss in whole-grain flour pasta which may be, in part, due to disruption in the gluten matrix by bran-germ particles, along with the presence of water-soluble components within the bran and aleurone layers or the higher fiber content (Manthey & Schorno, 2002; Sobota et al., 2015; West et al., 2013). In relation to this, WFAP presented a slightly higher cooking loss than WFBP, probably due to the differences in particle size distribution. Cyclonic mill (WFA) produced a large quantity of intermediate size particles while blade mill (WFB) produced larger size particles; this means that bran particle in WFAP could generate a higher number of disruptions in the gluten network because for a given weight of bran, smaller bran particles have greater surface area that can lead to more interactions of reactive components with gluten interfering more with the protein-starch matrix which is related to OCT and water absorption results (Noort, Haaster, Hemery, Schols, & Hamer, 2010).

3.4. Cooked pasta texture analysis

The textural characteristics of pasta play an essential role in determining consumer's acceptance. Particularly, hardness is important in pasta cooking quality. Pasta textural attributes results are presented in Table 3.

Hardness values were between 17.9 and 36.7 N. Statistically significant differences were found in all pasta samples. WFAP and WFBP samples were harder than those found in FP. The same trend was noted by various authors (Aravind et al., 2012; Bagdi et al., 2014; Sozer et al., 2007) who found a direct relationship between aleurone content or bran and germ incorporation and cooked pasta hardness. On the basis of different studies (Aravind et al., 2012; Grant, Dick, & Shelton, 1993), it can also be supposed that the relatively high lipid content of whole-grain pasta (Table 1) contributes to higher hardness as compared to that in FB. The presumed theory behind this phenomenon is that a large amount of fat material reduces starch granule disruption by means of binding to the granules, ensuring a firm starch gel in the pasta, resulting in a firmer product. WFAP, which showed the higher content of particles below 125 μm compared to that in WFBP, also presented the highest hardness values (Table 3). Niu, Hou, Lee, and Chen (2014) also showed greater hardness and chewiness in noodles with decreasing particle size as well. This observation means that the great number of small particles could be homogenously distributed in pasta structure generating greater hardness. No significant differences were observed between the two genotypes, except WFAP made from Baguette Premium 11 which presented the highest hardness value. This result agrees with the higher proportion of small particles found in WFAP for Baguette Premium 11 than in Klein Guerrero (Fig. 1).

Cohesiveness can be a good indicator of how the sample holds together upon cooking; the values observed were within the range of 0.49–0.54. No significant differences were found between the different milling techniques or genotypes. Chewiness values, which are related to the elastic strength of the protein matrix, were between 10.1 N and 19.9 N and were maximum for WFAP. In relation to genotypes, differences between both genotypes were not observed in the pasta.

In conclusion FP presented higher WA, SI values than whole-grain flour pasta meanwhile whole-grain flour pasta presented higher hardness and chewiness values. However, no significant differences were found in the three types of pasta analyzed for cooking loss and cohesiveness values.

3.5. Color of cooked pasta

Color of FP and whole-grain pasta is shown in Fig. 2. Lightness (L*) values varied between 57.3 and 62.3 in FP; and between 47.9 and 52.5 in both whole-grain pasta, while the yellowness-blueness (b*) presented values between 8.6 and 11.5 in FP and between 11.8 and 14.2 in whole-

Table 2
Pasta cooking parameters of all pasta samples and both genotypes.[a,b,c]

Sample	Genotype	OCT (min)	WA (%)	SI (%)	CL (%)
FP	Klein Guerrero	17 aC	129.6 ± 2.0 aB	1.8 ± 0.0 aB	5.5 ± 0.0 aA
	Baguette Premium 11	18bC	150.6 ± 1.9bB	2.0 ± 0.1bB	6.1 ± 0.7 aA
WFAP	Klein Guerrero	14bA	119.8 ± 1.9 aA	1.6 ± 0.0 aA	6.4 ± 0.4 aA
	Baguette Premium 11	13 aA	118.7 ± 0.4 aA	1.6 ± 0.0 aA	6.1 ± 0.0 aA
WFBP	Klein Guerrero	15 aB	129.7 ± 3.4 aB	1.7 ± 0.0 aA	5.6 ± 0.0 aA
	Baguette Premium 11	15 aB	133.8 ± 8.0 aB	1.8 ± 0.1 aA	5.7 ± 0.1 aA

[a] The data are the means of two independent experiments ± standard deviations (n = 2).
[b] FP: white flour pasta; WFAP: whole-grain flour A pasta; WFBP: whole-grain flour B pasta; OCT: Optimal Cooking Time; WA: Water Absorption; SI: Swelling Index; CL: Cooking Loss.
[c] Different capital letters within the same column represent significant pasta differences (P ≤ 0.05) while different lowercase letters within the same column represent significant genotype differences in each type of pasta (P ≤ 0.05).

Table 3
Texture analysis of all cooked samples in both genotypes.[a,b,c]

Sample	Genotype	Hardness (N)	Cohesiveness	Chewiness (N)
FP	Klein Guerrero	22.70 ± 3.32 aA	0.54 ± 0.06 aA	12.40 ± 3.12 aA
	Baguette Premium 11	17.92 ± 0.45 aA	0.52 ± 0.01 aA	10.10 ± 0.57 aA
WFAP	Klein Guerrero	31.20 ± 0.66 aC	0.51 ± 0.02 aA	15.90 ± 0.07 aB
	Baguette Premium 11	36.70 ± 0.03bC	0.49 ± 0.01 aA	19.90 ± 1.85 aB
WFBP	Klein Guerrero	26.30 ± 0.38 aB	0.51 ± 0.01 aA	13.40 ± 0.29 aA
	Baguette Premium 11	26.10 ± 0.12 aB	0.50 ± 0.01 aA	13.20 ± 0.06 aA

[a] The data are the means of two independent experiments ± standard deviations (n = 2).
[b] FP: white flour pasta; WFAP: whole-grain flour A pasta; WFBP: whole-grain flour B pasta.
[c] Different capital letters within the same column represent significant pasta differences (P ≤ 0.05) while different lowercase letters within the same column represent significant genotype differences in each type of pasta (P ≤ 0.05).

grain pastas. The redness-greenness (a*) tonality showed values between 1.9 and 2.5 in FP and between 6.1 and 8.2 in whole-grain pasta. FP samples had significantly higher values of L* and lower values of a* and b* compared to whole-grain pasta. The darkening of the pasta and the increase of the redness-greenness tonality can be explained by the presence of bran. Different authors (Aravind et al., 2012; Chen et al., 2011; Chillo, Laverse, Falcone, Protopapa, & Nobile, 2008) established that the increasing addition of bran causes a darkening and an increasing of the red color when compared whole-grain pasta and pasta made from semolina. No significant differences were found between both types of whole-grain pasta for a* and b* parameters, however WFBP presented higher L* values than WFAP. Whole-grain pasta made from Klein Guerrero showed significantly higher values of L* and b*, indicating the presence of brighter and more intensely colored pasta compared to pasta made from Baguette Premium 11.

3.6. Nutritional attributes of cooked pasta

3.6.1. Antioxidant activity

There are two main mechanisms by which a component can exert its antioxidant action: transfer of a hydrogen atom (determined as the radical scavenging activity) and transfer of an electron (determined as the reducing power) (Prior et al., 2005).

Antioxidant activity was determined as total phenolic content (TPC), radical scavenging activity (ABTS method) and reducing power (FRAP method) content in all uncooked and cooked pasta samples (Table 4).

Total polyphenol content varied between 4.32 and 7.39 mg GA/g pasta on uncooked pasta and between 0.36 and 0.86 mg GA/g pasta on cooked pasta. The radical scavenging activity (RSA) and reducing power (RP) values of uncooked pasta samples ranged from 1.75 to 4.61 and 0.57 to 2.52 respectively meanwhile on cooked pasta ranges from 0.82 to 2.05 and from 0.21 to 0.60 respectively. Uncooked pasta recorded the highest TPC, RSA and RP values. There was a 91.23% overall decrease in TPC for FP and an 87.5% decrease for whole-grain pasta after cooking. Hirawan, Yuin Ser, Arntfield, and Beta (2010) also found a reduction (40%) in total phenolic content of both regular and whole wheat spaghetti brands after cooking as well as Fares et al. (2008) who observed a dramatic decrease (95%) of antioxidant compounds in pasta after cooking. There is very little literature on phenolic content and antioxidant properties of processed bread wheat, particularly the recently introduced whole wheat pasta products. Different compounds exhibiting antioxidant activity are known to be present in significant amounts in whole grain products.

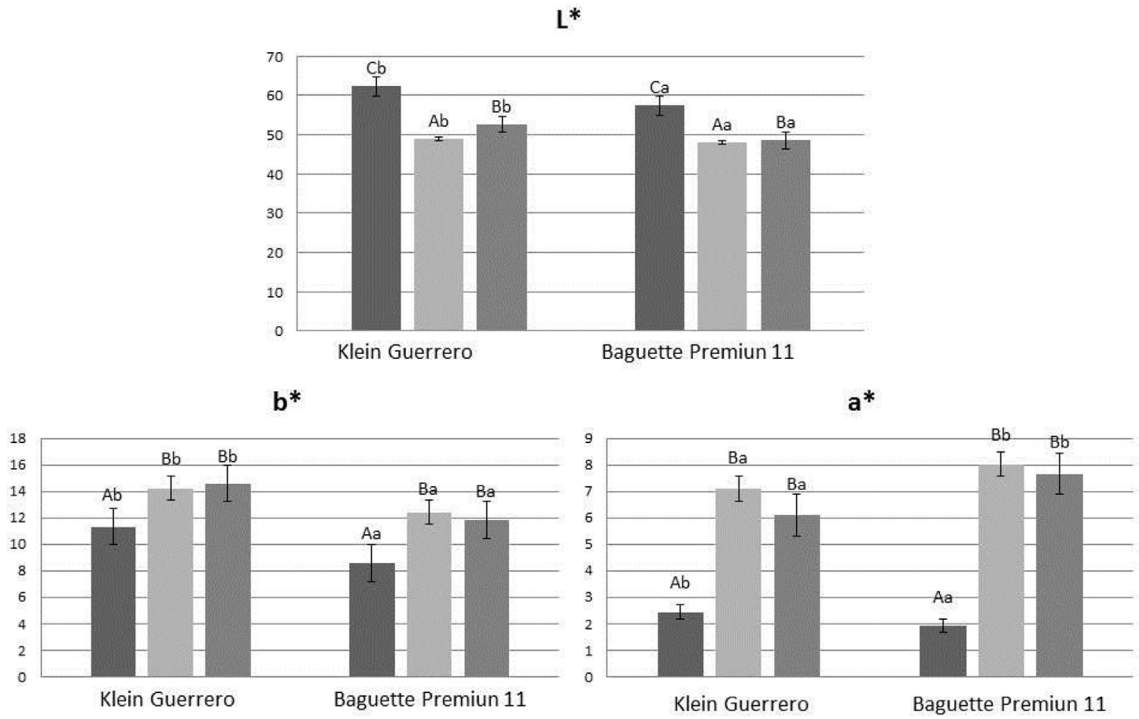

Fig. 2. Color of cooked pasta of all samples on both cultivars. FP: white flour pasta ■; WFAP: whole flour A pasta ■; WFBP: whole flour B pasta ■. Different capital letters represent significant pasta differences (P ≤ 0.05) while different lowercase letters represent significant genotype differences in each type of pasta (P ≤ 0.05).

Table 4
Total phenolic content (TPC), radical scavenging activity (RSA) and reducing power (RP) content in all uncooked and cooked pasta samples.[a,b,c]

	Sample	Genotype	TPC (mg GA/g pasta)	RSA (μmol trolox/g pasta)	RP (μmol trolox/g pasta)
UNCOOKED	FP	KG	5.49 ± 0.25bA	1.75 ± 0.07 aA	0.68 ± 0.01bA
		BP 11	4.32 ± 0.27 aA	3.07 ± 0.19bA	0.57 ± 0.01 aA
	WFAP	KG	7.39 ± 1.80bB	2.08 ± 0.06 aA	2.52 ± 0.04bB
		BP 11	5.22 ± 0.48 aB	4.61 ± 0.19bA	1.52 ± 0.00 aB
	WFBP	KG	6.68 ± 0.19bB	2.58 ± 0.51 aA	2.07 ± 0.08bB
		BP 11	5.35 ± 0.21 aB	4.13 ± 0.02bA	1.68 ± 0.05 aB
COOKED	FP	KG	0.50 ± 0.00 aA	0.86 ± 0.01 aA	0.21 ± 0.00 aA
		BP 11	0.36 ± 0.00 aA	0.82 ± 0.00 aA	0.26 ± 0.00 aA
	WFAP	KG	0.86 ± 0.00bB	2.04 ± 0.01 aB	0.50 ± 0.00 aB
		BP 11	0.65 ± 0.00 aB	1.67 ± 0.04 aB	0.60 ± 0.00 aB
	WFBP	KG	0.83 ± 0.00 aB	1.98 ± 0.00 aB	0.49 ± 0.00 aB
		BP 11	0.77 ± 0.07 aB	2.05 ± 0.01 aB	0.56 ± 0.00 aB

[a] The data are the means of two independent experiments ± standard deviations (n = 2).
[b] FP: white flour pasta; WFAP: whole-grain flour A pasta; WFBP: whole-grain flour B pasta; TPC: total polyphenol content; RSA: Radical scavenging activity; RP: reducing power.
[c] Different capital letters within the same column represent significant pasta differences (P ≤ 0.05) while different lowercase letters within the same column represent significant genotype differences in each type of pasta (P ≤ 0.05).

As expected, the highest TPC were obtained for whole-grain pasta in both uncooked and cooked samples. Moreover, whole-grain pasta also presented statistically higher RSA and RP values than FP except for RSA on uncooked samples. However, no significant differences were observed between both whole-grain pasta for any antioxidant activity suggesting that flour particle size did not affect the antioxidant capacity of pasta. Hirawan et al. (2010) also found that whole-grain pasta brands exhibited increased phenolic compounds content and ferulic acid compared to semolina spaghetti. Outer membranes of the grain, especially bran fraction, contained higher concentrations of phenolic acids than those in endosperm. In addition, bran fractions also contained carotenoids with a significant input to the final antioxidant capacity of the flour (Lv et al., 2012).

Both types of antioxidant activities, RP and RSA presented the same tendency on uncooked and cooked pasta (Table 4). Because higher absolute values were observed in the determination of the RSA, it can be established that it is the antioxidant mechanism that predominates in our pasta samples. Pasta made from Klein Guerrero presented higher TPC content in both uncooked and cooked samples than pasta made from Baguette Premium 11 although difference was not significant only in FP and WFBP on cooked samples. Uncooked pasta made from Baguette Premium 11 presented the highest RSA values while pasta made from Klein Guerrero recorded the highest RP values. Regarding cooked pasta, no differences were observed in RSA and RP between both cultivars for each pasta type.

3.6.2. Total dietary fiber

Total dietary fiber values (g/100 g pasta) ranged from 4.9 to 13.9 g/100 g (Table 5). All whole-grain pasta showed higher total dietary fiber values than FP demonstrating that wheat bran is a mayor dietary fiber source (Chen et al., 2011; Seibel, 1996). No significant differences between both whole-grain flours pasta were found. In relation to genotypes, although pasta made from Baguette Premium 11 displayed higher total dietary fiber than those seen in pasta made from Klein Guerrero, statistically differences were only showed for WFAP.

3.6.3. Starch analysis and protein pasta content

Table 5 summarizes total starch, resistant starch and protein pasta content. The content of total starch varied from 45.9 to 65.9 g/100 g and resistant starch values were lower than 1% except in Baguette Premium 11. The lower starch content of whole-grain flour pasta was caused by a bran dilution effect, as detected by Sobota et al. (2015) in semolina and whole-grain durum pasta, although the total starch values recorded were higher than ours (semolina 76.3%, whole-grain durum 73.3%). No significant differences between both whole-grain flours pasta were found. In relation to genotypes, although no significant differences were observed, pasta made from Baguette Premium 11 displayed higher total starch values than those seen in pasta made from Klein Guerrero. The protein content in cooked pasta ranged from 14.7% to 19.5%. There was more protein content in of cooked pasta than in flours as a result of the loss of solids during cooking which leads to the concentration of the remnant nutrients within pasta structure. Similar protein values were recorded by Hirawan and Beta (2014) in whole-wheat macaroni. Sobota et al. (2015) found lower protein content in semolina and whole-grain durum pasta (13.4% and 13.4%, respectively). Pasta made from Klein Guerrero had higher protein content in the three pasta types than that in Baguette Premium 11, in agreement with protein flour content (Table 1). However no significant differences were found when whole-grain and white flour pasta were compared. These findings show that the differences expressed in milling procedure used to produce varying degrees of particle size in flour did not affect protein content.

Table 5
Total starch, resistant starch, protein and fiber content in cooked pasta.[a,b,c]

Sample	Genotype	Total Starch g/100 g	Resistant Starch g/100 g total starch	Protein g/100 g	Fiber g/100 g
FP	Klein Guerrero	64.3 ± 1.9 aB	0.7 ± 0.0 aB	16.7 ± 0.2bA	4.9 ± 0.2 aA
	Baguette Premium 11	65.9 ± 1.7 aB	1.8 ± 0.2bB	15.5 ± 0.8 aA	5.4 ± 0.1 aA
WFAP	Klein Guerrero	45.8 ± 3.9 aA	0.7 ± 0.0 aA	19.5 ± 0.2bA	11.6 ± 0.5 aB
	Baguette Premium 11	49.8 ± 0.4 aA	1.9 ± 0.1bA	14.9 ± 0.0 aA	13.5 ± 0.6bB
WFBP	Klein Guerrero	50.7 ± 2.8 aA	0.9 ± 0.1 aA	18.6 ± 1.3bA	11.8 ± 0.6 aB
	Baguette Premium 11	51.1 ± 2.9 aA	1.8 ± 0.1bA	15.9 ± 0.0 aA	13.9 ± 0.3 aB

[a] The data are the means of two independent experiments ± standard deviations (n = 2).
[b] FP: white flour pasta; WFAP: whole-grain flour A pasta; WFBP: whole-grain flour B pasta.
[c] Different capital letters within the same column represent significant pasta differences (P ≤ 0.05) while different lowercase letters within the same column represent significant genotype differences in each type of pasta (P ≤ 0.05).

4. Conclusion

This study has shown that pasta made from whole-grain flour showed good performance after cooking. No difference in cooking loss, cohesiveness and chewiness between whole-grain and white flour pasta was recorded, although whole-grain pasta showed greater hardness and lower values of water absorption, swelling index and OCT. This indicates that the presence of bran modifies the structure of pasta, interfering with gluten-starch matrix. On the other hand, particle size of whole-grain flour influenced cooking parameters as OCT and WA, suggesting that pasta made from whole-grain flour with larger particle size would be of better quality.

Whole-grain pasta is promising in value-added food production due to its high polyphenol and total dietary fibre content. Flour particle size did not influence on protein and antioxidant content, suggesting that the loss of these compounds during cooking could not be related to these characteristics. These results illustrate the potentiality and functionality of whole-grain flour to increase pasta nutritive value. Even though whole-grain flour pasta did not show the same technological quality as that in white flour pasta, cooking and textural characterization of whole-grain pasta showed good performances.

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