Food Chemistry 119 (2010) 1544–1549

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Quality of spaghetti pasta containing Mexican common bean flour (*Phaseolus vulgaris* L.)

J.A. Gallegos-Infante [a,*], N.E. Rocha-Guzman [a], R.F. Gonzalez-Laredo [a], L.A. Ochoa-Martínez [a], N. Corzo [b], L.A. Bello-Perez [c], L. Medina-Torres [d], L.E. Peralta-Alvarez [a]

[a] Instituto Tecnológico de Durango, Departamento de Ings, Química y Bioquímica, Blvd. Felipe Pescador 1830 Ote. Col. Nueva Vizcaya, CP 34080, Durango, Dgo, Mexico
[b] Instituto de Fermentaciones Industriales (CSIC), C/Juan de la Cierva, 3, Madrid 28006, Spain
[c] CEPROBI–IPN, Centro de Desarrollo de Productos Bióticos del Instituto Politécnico Nacional, Yautepec, Morelos, Mexico
[d] Departamento de Ingeniería Química, Facultad de Química, Edificio "E", Lab-213 Universidad Nacional Autónoma de México, UNAM, 04510 México, DF, Mexico

ARTICLE INFO

Article history:
Received 2 May 2009
Received in revised form 18 August 2009
Accepted 10 September 2009

Keywords:
Common bean
Cooking quality
Furosine
Spaghetti pasta
Phenolics

ABSTRACT

The objective of this research was to study the effect of the addition of common bean flour to semolina on the cooking quality and total phenolic content of pasta. Pasta was obtained at three temperatures (60, 70 and 80 °C) and two levels of added common bean flour (15% and 30%); plain pasta (100% semolina) was used as control. Moisture, optimal cooking time, cooking loss, water absorption capacity, colour change, firmness and total phenolic and furosine contents were measured. The cooking time and water absorption were diminished in spaghetti pasta with added common bean flour; cooking loss increased and firmness decreased as a function of the bean flour percentage. A linear relationship between colour change and common bean flour content in pasta was found. Increases of furosine and phenolic contents in pasta with the addition of bean flour were observed.

1. Introduction

Spaghetti pasta is a traditional product generally made from semolina, which is considered the best raw material (Malcolmson, Matsuo, & Balshaw, 1993); its consumption has increased, due to its ease of transportation, handling, cooking and preparation (Tudorica, Kuri, & Brennan, 2002). Spaghetti pasta is recognised as low in sodium and fat with no cholesterol and a rich source of complex carbohydrates (Giese, 1992), producing a low post-prandial response to glucose and insulin in the blood (Cleary & Brennan, 2006).

The World Health Organization (WHO) and Food and Drug Administration (FDA) consider spaghetti pasta a good vehicle for the addition of nutrients (Chillo, Laverse, Falcone, Protopapa, & Del Nobile, 2008). In 1940s spaghetti pasta was one of the first foods which the FDA permitted vitamin and iron enrichment (Marconi & Carcea, 2001). However, it is low in protein and in essential amino acids, such as lysine and threonine. Thus, several studies have been carried out to improve the protein content of spaghetti pasta by the addition of raw materials of vegetable origin (Bahnassey & Khan, 1986). Other authors have studied the effect of the addition of dietary fibres, vitamins and minerals on spaghetti pasta quality (Knuckles, Hudson, Chiu, & Sayre, 1997). High protein plant materials are derived mainly from soybean, pea and beans and can be used as isolates, flour or in their concentrated form, in order to increase the protein concentration. Nowadays, the need for consumption of food products with indigestible carbohydrates produced the development of spaghetti pasta with banana starch (Hernandez-Nava, Berrios, Pan, Osorio-Diaz, & Bello-Perez, 2009; Osorio-Diaz et al., 2008; Rendón-Villalobos, Osorio-Diaz, Agama-Acevedo, Tovar, & Bello-Perez, 2008) and unripe banana flour (Ovando-Martinez, Sayago-Ayerdi, Agama-Acevedo, Goñi, & Bello-Perez, 2009).

Common bean (*Phaseolus vulgaris*) is a traditional food in the human diet, low in fat and rich in proteins, vitamins, complex carbohydrates and minerals. Consumption of dry beans has been linked to reduced risk of diabetes and obesity (Geil & Anderson, 1994). Common beans have been reported as a good source of polyphenols with antioxidant and anticarcinogenic activities (Gamez et al., 1998). There are few works about the effect of thermal processing on the antioxidant activity of common beans (Jiratavan & Liu, 2004; Rocha-Guzman, Gonzalez-Laredo, Ibarra-Perez, Nava-Berumen, & Gallegos-Infante, 2007) and to our knowledge there are no reports about the effect of the addition of common bean flour to semolina on the antioxidant properties of spaghetti pasta.

* Corresponding author. Tel.: +52 618 8186936.
E-mail address: jinfante@itdposgrado-bioquimica.com.mx (J.A. Gallegos-Infante).

0308-8146/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2009.09.040

Spaghetti pasta quality can be expressed in terms of cooking characteristics, colour, taste and aroma, which are of great importance for the consumer (Chillo et al., 2008). The quality of spaghetti pasta cooking can be evaluated in terms of stickiness, firmness, overcooking tolerance, degree of swelling and loss of solids (Baiano, Conte, & Del Nobile, 2006).

The preparation of spaghetti pasta entails different steps: milling, dough formation and drying. The latter is a crucial operation for the quality of spaghetti pasta, since modifications of main components can take place. The traditional methods for drying spaghetti pasta use low temperatures, LT (29–40 °C) and longer treatment times, Lt (24–60 h, LT–Lt), but the use of low temperature treatments followed by higher temperatures, HT (60–80 or 80–100 °C) and shorter treatment times, St (5–12 h or 1–2 h, HT–St) has been widely accepted (Dexter & Matsuo, 1981).

Part of this research was dedicated to investigating non-enzymatic browning (NEB). In fact some products deriving from this reaction are considered useful indexes of spaghetti pasta quality, in particular ε-furoylmethyllysine (furosine) (Anese, Nicoli, Massini, & Lerici, 1999) and 5-(hydroxymethyl)-2-furancarboxaldehyde (HMF) (Acquistucci, Bassotti, & Cubadda, 1988). Highest levels of furosine indicate a low quality product, but Maillard reaction products (MRP) are known to possess scavenging activity on active oxygen species (Yoshimura, Iijima, Watanabe, & Nakazawa, 1997).

The fortification of spaghetti pasta with legume protein is relatively unusual (Dick & Youngs, 1988); only one work has been published in this respect for white lupin protein-enriched spaghetti (Doxastakis et al., 2007), whereas some scattered information is available in the case of other food systems, such as infant cereals (Guerra-Hernandez, Corzo, & Garcia-Villanova, 1999).

Another part of this research was to evaluate the effect of the addition of common bean flour (Bayo-Victoria) to semolina; there are several publications in this respect, but not for Bayo-Victoria beans. This cultivar is interesting because from a previous work (Rocha-Guzman et al., 2007), it has shown increasing antioxidant capacity after cooking.

2. Materials and methods

Semolina was gratefully donated by Barilla G. & R. Fratelli S.p.A (San Luis Potosí, Mexico). Bayo-Victoria beans were supplied by INIFAP Valle del Guadiana (harvesting season 2005–2006).

2.1. Pasta preparation

Pasta was prepared as shown in Fig. 1. Briefly, common bean was cleaned and cooked in a pressure cooker (All American, Model 921 21, Hillsville, VA), with a water relationship of 1:4 for 60 min at 15 psi. Cooked common beans were blended in a domestic food processor (Moulinex, Modelo AR6838, México, DF, Mexico) for 1 min. Composite spaghetti pasta was placed on the dryer surface and introduced at the dryer (Morko, Queretaro, Mexico) at 70 °C for 2 h. Dried spaghetti pasta was milled in a Buhler mill (Mod 911892, Carolina Beach, NC) and sieved (0.180 mm mesh). Common bean flour obtained was stored in hermetic bags at room temperature (20 °C).

Spaghetti pasta was prepared with semolina and different concentrations of common bean flour (0%, 15% and 30% w/w). For each formulation, semolina, common bean flour and water were mixed using a domestic blender (Kitchen Aid, Mod K5SSWH) for 5 min, to obtain homogeneous dough. This dough was formed and cut in a pasta machine (Pasta machina, Kitchen collection, Mod 20171, Chillicothe, OH). Samples obtained were pre-dried for 12 min at 30 °C in a tray.

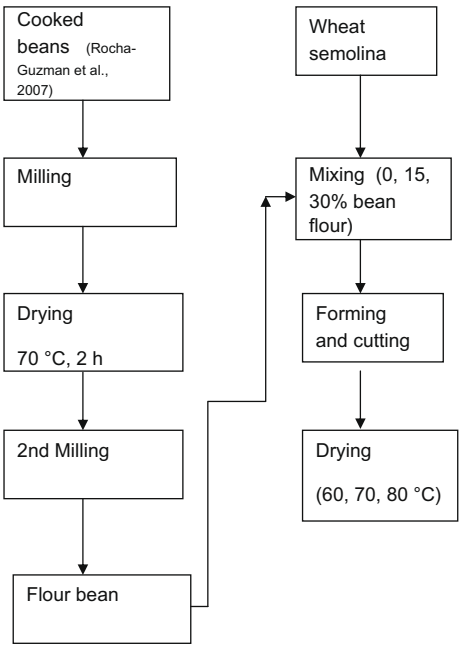

Fig. 1. Flow chart for pasta production.

2.2. Drying process

Spaghetti pasta was dried in a drying tray (Morko, Queretaro, Mexico). The drying process was carried out using three different temperatures (60, 70 and 80 °C) and two levels of added common bean flour (15% and 30%). Experiments were repeated twice.

2.3. Pasta quality evaluation

2.3.1. General

All analyses were carried out in duplicate. Water content was determined following AOAC Method No. 926.07 (AOAC, 1986).

2.3.2. Optimal cooking time and cooking loss

The optimum cooking time (min) for each sample was determined using AACC Method 66-50 (AACC, 2000). Spaghetti was considered cooked when its white core has disappeared after being pressed between two plastic plates.

The cooking loss expressed as percent, was measured by evaporating the spaghetti cooking water to dryness in an oven tray at 100 °C, as described by AACC Method 66-50 (AACC, 2000).

Protein content ($N \times 5.85$) was assessed according to AACC Method 46-13.

Water absorption capacity (WAC) was determined following the method described by Rocha-Guzmán et al. (2008).

2.3.3. Colour evaluation

The colour of dried spaghetti pasta was measured with a Hunter Lab Colorimeter (MiniScan XE Plus, Reston, VA). Briefly, spaghetti pasta samples were milled and sieved (0.425 mm mesh). Powder samples were placed in the colorimeter and the colour readings expressed by Hunter L^*, a^* and b^* values. Results were expressed as colour differential (ΔE) between control (pasta with 0% of common bean flour) and substituted spaghetti pasta, calculated as follows:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

where ΔL was calculated as: $L_{sample} - L_{control}$;
Δa was calculated as: $a_{sample} - a_{control}$;
and Δb was calculated as: $b_{sample} - b_{control}$.

Results are the means of independent duplicate determinations (Setiady, Lin, Younce, & Rasco, 2007).

2.3.4. Firmness

Firmness data were obtained using a texturometer (Texture Analyzer, TA-XT2i Stable Micro Systems, Godalming, UK) coupled to a PC with data acquisition and the software Texture Expert Version 1.22 (Stable Micro Systems). Firmness evaluation was performed following AACC Method 16-50 (AACC, 2000). Samples were cut (5 cm) at their optimal cooking time and put into the Warner–Bratzler apparatus.

2.3.5. Total phenolic content

Spaghetti pasta samples were cooked to their optimal cooking time. Cooked samples were drained for up to 1 min and placed in an Erlenmeyer flask (250 ml) and ultra frozen at −83 °C in an ultra freezer (Revco, Waltham, MA). Frozen samples were lyophilised (Labconco, Kansas City, MO), milled in a ceramic mortar and sieved (0.425 mm mesh).

Powdered spaghetti pasta samples (20 g) were defatted with 200 ml of chloroform:methanol (2:1) and stirred for 1 h. Then, solid residues were extracted with 70% aqueous acetone (200 ml) for 24 h at room temperature in agitation. Crude extracts were concentrated under vacuum at 40 °C in a rotary evaporator (Büchi, Model R-200/250, Flawil, Switzerland). The resulting aqueous solutions were lyophilised, milled in a ceramic mortar and sieved (0.425 mm mesh) and stored in the dark at 4 °C until analysis. Extractions were performed in duplicate. Experimental samples were always protected from light. Total phenolic content was determined according to the Folin–Ciocalteu method, following methodology reported by Gallegos-Infante, Rocha-Guzman, Gonzalez-Laredo, and Pulido-Alonso (2009). The total phenolic content was expressed as catechin equivalents (CE, mg catechin/g sample) using a catechin calibration curve (0–120 μg/ml, $r^2 = 0.993$).

2.3.6. Furosine

Chromatographic determination of furosine in spaghetti pasta samples was performed by ion-pair RP-HPLC, following the method of Resmini, Pagani, and Pellegrino (1990). Before analysis, pasta samples (350 mg) were hydrolysed with 8 ml of HCl (8 N) under inert conditions at 110 °C for 24 h in a screw-capped Pyrex vial with PTFE-faced septa.

The separation of furosine was realised using the method of Garcia-Baños, Corzo, Sanz, and Olano (2004). It was performed using a C_8 column (250 × 4.6 mm i.d., Alltech furosine dedicated); (Alltech Associates, Laarne, Belgium), thermostatted at 35 °C. A binary linear gradient was used. Furosine analysis was made using a binary gradient, eluent **A** (acetic acid in water, 0.4% v/v) and eluent **B** (KCl solution in water 0.3% w/v) with a flow of 1.2 ml/min (Resmini et al., 1990) with an injection volume of 50 μl. A Dionex chromatograph (DX-300, Sunnyvale, CA) and a variable wavelength detector at 280 nm (LDC Analytical, SM 4000) were used. Acquisition and data processing were achieved with HPChemStation (Hewlett–Packard) software. Quantitation was performed by the external standard method using a commercial standard of pure ε-2-furoylmethyl-L-lysine (furosine, Neosystems Laboratories, Strasbourg, France).

2.4. Statistical analysis

Factorial experimental design was used. Data were analysed by ANOVA ($p < 0.05$) test and *post hoc* comparison of means by Tukey test using Statistica V. 7.0 (StatSoft, Tulsa, OK). Each treatment was performed with at least two and in some cases up to five replicates.

3. Results and discussion

3.1. Moisture

Moisture data are shown in Table 1. The moisture content of spaghetti pasta decreased when temperature increased. This pattern is related to the effective moisture diffusivity that increases with drying temperature, following an Arrhenius-type equation (Villenueve & Gelinas, 2007). Adding 15% of common bean flour did not show statistical differences, but when 30% was added, lower moisture was observed, as reported previously for spaghetti samples with banana flour (Ovando-Martinez et al., 2009) and for spaghetti containing light and dark buckwheats (Rayas-Duarte, Mock, & Saterlee, 1996).

3.2. Protein

The protein content of spaghetti pasta increased with increased common bean flour in the spaghetti (Table 1), independent of the processing temperature. The protein increase was associated with the amount of common bean flour added. Ovando-Martinez et al. (2009) reported a protein content of 9.35% for spaghetti with banana flour (30%), but in spaghetti with common bean flour (30%), protein content was 16.68% (see Table 1).

3.3. Optimal cooking time

The optimal cooking times (OCT) of pasta samples with common bean flour are reported in Table 1. Results showed that optimal cooking time was affected only by drying temperature ($p < 0.05$). The lowest OCT obtained was recorded for spaghetti pasta dried at 80 °C, independently of the concentration of common bean flour. Several authors (Baiano et al., 2006; Del Nobile, Baiano, Conte, & Mocci, 2005) reported lower OCT with higher drying temperatures for spaghetti pasta made with semolina; these authors explained the lower OCT by suggesting that the gluten network is better formed at the highest temperature.

3.4. Water absorption capacity

Water absorption capacity (WAC) results are shown in Table 2. There are influences of the statistical interaction between temperature and concentration of common bean flour added to the spaghetti pasta ($p < 0.05$).

Spaghetti pasta control (0%) showed the highest water absorption (29.9 ml/g) at the highest drying temperature (80 °C). This behaviour is contrary to the report from Baiano et al. (2006), who found a decrease in water absorption in pasta made with semolina, when increasing drying temperature. Pasta with 15% of common bean flour and dried at 60 °C showed the second higher value

Table 1
Moisture, protein and optimal cooking time data for pasta samples with added common bean flour.

Sample	Moisture (%)	Protein (%)	Optimal cooking time (min)	Processing temperature (°C)
Control	6.35 ± 0.15^{a}	12.50 ± 0.01^{a}	4.46 ± 0.10^{a}	60
Control	4.15 ± 0.15^{b}	12.50 ± 0.01^{a}	4.35 ± 0.06^{a}	70
Control	3.15 ± 0.15^{c}	12.50 ± 0.01^{a}	3.24 ± 0.02^{b}	80
15%	6.25 ± 0.05^{a}	14.50 ± 0.01^{b}	4.80 ± 0.20^{a}	60
15%	4.60 ± 0.10^{d}	14.50 ± 0.01^{b}	4.25 ± 0.04^{a}	70
15%	3.60 ± 0.40^{c}	14.50 ± 0.01^{b}	3.34 ± 0.04^{b}	80
30%	4.75 ± 0.25^{d}	16.68 ± 0.02^{c}	4.76 ± 0.27^{a}	60
30%	3.05 ± 0.05^{c}	16.68 ± 0.02^{c}	4.03 ± 0.02^{c}	70
30%	2.55 ± 0.15^{e}	16.68 ± 0.02^{c}	3.31 ± 0.10^{b}	80

[a–e] Different letters in same column indicate statistical differences ($p < 0.05$).

Table 2
Water absorption capacity, cooking loss and firmness data for pasta with added common bean flour.

Sample	Water absorption capacity (%)	Cooking loss (%)	Firmness (grf)	Temperature (°C)
Control	26.00 ± 0.20[a]	9.95 ± 0.91[a]	177 ± 9.14[a]	60
Control	28.05 ± 0.45[b]	10.17 ± 0.57[a]	183 ± 15.8[a]	70
Control	29.90 ± 1.10[b]	11.78 ± 0.57[a]	174 ± 13.8[a]	80
15%	28.85 ± 0.65[b]	14.91 ± 0.34[b]	136 ± 10.2[b]	60
15%	27.40 ± 0.60[c]	14.20 ± 1.00[b]	128 ± 3.03[b]	70
15%	24.85 ± 1.05[d]	14.20 ± 0.64[b]	122 ± 3.97[b]	80
30%	27.75 ± 0.95[b]	21.56 ± 0.46[c]	101 ± 2.96[c]	60
30%	28.05 ± 0.55[b]	21.36 ± 2.42[c]	108 ± 10.5[c]	70
30%	25.65 ± 0.15[d]	19.44 ± 0.40[c]	139 ± 6.14[b]	80

[a–d] Different letters in same column indicate statistical differences ($p < 0.05$).

of WAC (28.85 ml/g). This behaviour could be explained as a function of the thermal treatment applied to the legumes. Several authors (Enwere, McWalters, & Phillips, 1998; Granito, Guerra, Torres, & Guinand, 2004) reported greater water absorption capacity in thermally processed legumes; they claim that this behaviour is associated to the denaturation of proteins, particularly albumins. However, the lowest value of WAC was obtained at 15% common bean flour and 80 °C drying temperature (24.85 ml/g), which suggests that not only proteins play an important role in water absorption. In this sense, Köber, Gonzalez, Gavioli, and Salmoral (2007) reported that water absorption is a function of the amylose/amylopectin ratio and the chain length distribution of amylopectin.

3.5. Cooking loss

The common bean flour content increased the cooking loss (Table 2), with significant differences between the control and samples containing 15% and 30% of bean flour ($p < 0.05$). Whole durum wheat is employed in high quality pasta manufacturing, due to the unique rheological properties of its proteins. Cooking loss for a good quality pasta should be lower than 12% (Hoseney, 1999) and a partial or complete substitution of durum wheat with another material can result in negative changes (Cleary & Brennan, 2006), as was found when using 5–30% of yellow peas, lentils and chickpeas (Zhao, Manthey, Chang, & Yuan, 2005) and 15% of banana flour (Ovando-Martinez et al., 2009). Our spaghetti control exhibited the lowest cooking loss, but it was higher than 4.73%, reported by Ovando-Martinez et al. (2009), and 6.5%, by Hernandez-Nava et al. (2009), for spaghetti made of 100% semolina. However, the cooking loss was lower than those (5–30%) determined by Granito, Torres, and Guerra (2003).

Granito et al. (2003) found that temperature had an influence on the cooking loss. They indicated that using higher temperatures in pasta drying will produce lower cooking losses. In the present work, the behaviour was different, in part because we used 15% and 30% of common bean flour. Thus in the control, at higher drying temperature the cooking loss has increased; at 15%, the temperature did not show an influence on the cooking loss; at 30% our results agreed with Granito et al. (2003), and at higher temperatures, there was a lower cooking loss.

The addition of non-gluten flours in the production of spaghetti was reported to dilute the gluten strength of semolina, and to interrupt and weaken the overall structure of the spaghetti. This might allow more leaching out of solids from pasta into the cooking water (Rayas-Duarte et al., 1996).

3.6. Firmness

The firmness results for spaghetti pasta samples are shown in Table 2. The control showed the highest firmness; temperature did not influence firmness ($p > 0.05$). Lowest firmness was found in the sample with 30% of common bean flour and the use of low temperatures. Bergman, Gualberto, and Weber (1994) found that using higher temperatures increased the firmness of pasta; this behaviour agrees with that observed for pasta with higher bean flour (30%), but not for pasta with 15% bean flour and the control.

Bergman et al. (1994) indicated that temperatures between 70 and 90 °C are enough to denature proteins, induce the formation of a protein–carbohydrate–lipid matrix, and inhibit the solubilisation of starch in water.

The observed behaviour for pasta with 15% common bean flour is in agreement with Granito et al. (2003), who detected a lower firmness value in pasta with 15% common bean flour. They claim that this behaviour is a function of the nature of the matrix and a dilution phenomenon. In this case, we found a significant negative correlation ($r^2 = 0.93$) between cooking loss and firmness. These results agree with those reported for pasta with added amaranth flour (Chillo et al., 2008).

3.7. Colour change

Results obtained for colour change are shown in Table 3. The lowest difference in colour was found for spaghetti pasta with 15% common bean flour and drying at 60 °C, but no differences were observed between 70 and 80 °C, for that concentration of common bean flour. Pasta with 30% common bean flour did not show differences at any temperatures tested. The difference in colour was associated with the use of common bean flour ($p < 0.05$) rather than the temperature assayed. This result does not agree with Gowen, Abu-Ghannam, Frias, and Oliveira (2007), who reported that the change of colour in pasta with peas was associated with the drying temperature. However, results obtained in the present work agree with Setiady et al. (2007), who found that an increase of fish flour in pasta noodles enhanced the colour change. Composite spaghetti pasta showed darker colour. Dry spaghetti colour is an important quality factor for consumers (Rayas-Duarte et al., 1996). Samples with more bean flour were darker. However, the market for composite pastas (that actually are darker) has grown and expanded (Shelke, 2006).

3.8. Furosine evaluation

Furosine was selected in this research as a molecular marker of non-enzymatic browning. It is produced by acid hydrolysis of the Amadori compounds that are formed in the Maillard reaction between reducing sugars and proteins (Resmini et al., 1990). Furosine is considered a useful marker in the thermal treatment of different food products, and is correlated to industrial process parameters or

Table 3
Furosine, total phenols content and colour data for pasta added with common bean flour.

Sample	Furosine (mg/100 g of protein)	Total phenols content (mg of catechin equivalent/g of sample)	Difference in colour (ΔE)	Temperature (°C)
Control	32.5 ± 0.14[a]	4.98 ± 0.84[a]	–	60
Control	25.5 ± 0.57[a]	5.51 ± 0.41[a]	–	70
Control	26.3 ± 0.22[a]	5.42 ± 0.79[a]	–	80
15%	51.7 ± 2.19[b]	6.57 ± 0.09[ab]	16.1 ± 2.43[b]	60
15%	41.4 ± 0.49[c]	6.45 ± 0.31[ab]	19.6 ± 0.04[bc]	70
15%	56.9 ± 4.24[b]	8.20 ± 0.27[bc]	21.1 ± 3.58[bc]	80
30%	70.4 ± 0.57[d]	6.84 ± 0.18[ab]	26.7 ± 0.77[c]	60
30%	53.5 ± 2.12[c]	9.68 ± 0.74[c]	25.8 ± 2.58[c]	70
30%	77.0 ± 0.01[d]	8.13 ± 1.05[bc]	28.3 ± 4.27[c]	80

[a–d] Means in a column with different superscripts are significantly different (Tukey test, $p < 0.05$).

to useful quality indices during storage (Ramirez-Jimenez, Guerra-Hernández, & Garcia-Villanova, 2003).

Furosine results (Table 3) showed that the lowest values of furosine were obtained for spaghetti pasta without common bean flour (<32.5 mg furosine/100 g protein). Furosine concentrations found in the present work were lower than those reported for spaghetti pasta made with semolina and similar to values for fresh pasta (Garcia-Baños et al., 2004). In general, higher values of furosine were observed in samples higher in common bean flour and dried at higher temperature ($p < 0.05$). According to quality indices, higher concentration of furosine indicates poor quality product (Ramirez-Jimenez et al., 2003). According to scavenging effect, higher levels of furosine could be related with increased scavenging effect on active oxygen species (Yoshimura et al., 1997).

3.9. Total phenolic content

Total phenolic contents in the experimental samples are shown in Table 3. In general, higher values of total phenols content in spaghetti pasta were observed in samples with more common bean flour. There are no reports about this behaviour in pasta, although there are many papers about antioxidants in common beans. In particular, Rocha-Guzman et al. (2007) reported the highest phenolic values for Bayo-Victoria common bean cultivar, in comparison with other cultivars, when they were cooked.

Temperature affects the total phenolic content positively in spaghetti pasta. Generally, at higher temperatures, higher phenolic contents were observed; this phenomenon was similarly observed by Fernandez, Elias, Braham, and Bressani (1982), who argued a cleavage of polyphenol polymers occurred, increasing the associated presence of more simple phenolic molecules. In this sense Xu, Ye, Chen, and Liu (2007) reported increasing phenolic acids content in cooked common beans. However, the Folin–Ciocalteu method may overestimate the total phenolic content because Maillard products might react with the Folin–Ciocalteu reagent (Verzelloni, Tagliazucchi, & Conte, 2007); more experimental work is necessary to elucidate the actual phenolic content and the antioxidant capacity related to the Maillard reaction products or polyphenols.

4. Conclusions

The addition of common bean Bayo-Victoria flour to spaghetti pasta affects their cooking time and water absorption characteristics; these were diminished in pasta with common bean flour. Cooking loss increases and firmness decreases as a function of the concentration of common bean flour added to the pasta. There is a linear relationship between colour change and amount of common bean flour present in the pasta. There are increases of furosine in pasta with added common bean flour, but the levels of furosine were similar to those found in fresh pasta made with 100% wheat semolina. There is an apparent increase of total phenolic content as a function of the common bean flour added to the pasta.

Acknowledgements

This work was supported partially by the Mexican Ministry of Education (SEP–DGEST) and the National Council for Science and Technology (CONACYT–Mexico). Author LEPA thanks Graduate Scholarship from CONACYT–Mexico.

References

AACC (2000). *AACC international approved methods of analysis* (10th ed.). St. Paul, MN, USA: American Association of Cereal Chemist.

Acquistucci, R., Bassotti, G., & Cubadda, R. (1988). Effects of high temperature drying on some nutritional characteristics of pasta. In R. Walker & E. Quattrucci (Eds.), *Nutritional and toxicological aspects of food processing* (pp. 163–197). London: Taylor and Francis.

Anese, M., Nicoli, M. C., Massini, R., & Lerici, C. R. (1999). Effects of drying processing on the Maillard reaction in pasta. *Food Research International, 32*(2), 193–199.

AOAC (1986). *Official methods of analysis* (16th ed., p. 1298). Washington, DC: Association of Official Analytical Chemistry.

Bahnassey, Y., & Khan, K. (1986). Fortification of spaghetti with edible legumes. II. Rheological, processing and quality evaluations studies. *Cereal Chemistry, 63*(2), 216–219.

Baiano, A., Conte, A., & Del Nobile, M. A. (2006). Influence of drying temperature on the spaghetti cooking quality. *Journal of Food Engineering, 76*(2), 341–347.

Bergman, C., Gualberto, D., & Weber, C. (1994). Development of high-temperature-dried soft wheat supplemented with cowpea (*Vigna unguiculata* L. Walp) cooking quality, color and sensory evaluation. *Cereal Chemistry, 71*(4), 523–527.

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*(1), 144–152.

Cleary, L., & Brennan, C. (2006). The influence of a (1 → 3) (1 → 4)-β-D-glucan rich fraction from barley on the physical–chemical properties and in vitro reducing sugars release of durum wheat pasta. *International Journal of Food Science and Technology, 41*(7), 910–918.

Del Nobile, M. A., Baiano, A., Conte, A., & Mocci, G. (2005). Influence of protein content on spaghetti cooking quality. *Journal of Cereal Science, 41*(3), 347–356.

Dexter, J., & Matsuo, R. (1981). Relationship between durum wheat protein properties and pasta dough rheology and spaghetti cooking quality. *Journal of Agriculture and Food Chemistry, 28*(3), 899–902.

Dick, J. W., & Youngs, V. L. (1988). Evaluation of durum wheat, semolina and pasta in the United States. In G. Fabriani & C. Lintas (Eds.), *Durum wheat: Chemistry and technology* (pp. 237–248). St. Paul, MN, USA: American Association of Cereal Chemist.

Doxastakis, G., Papageorgiou, M., Mandalou, D., Irakli, M., Papalamprou, E., D'Agostina, A., et al. (2007). Technological properties and non-enzymatic browning of white lupin protein enriched spaghetti. *Food Chemistry, 101*(1), 57–64.

Enwere, N. J., McWalters, K. H., & Phillips, R. D. (1998). Effect of processing on some properties of frijol seed, protein, starch, flour and akara. *International Journal of Food Science and Nutrition, 49*(3), 365–373.

Fernandez, R., Elias, L. G., Braham, J. E., & Bressani, R. (1982). Trypsin inhibitors and hemagglutinating in beans (*Phaseolus vulgaris* L.) and their relationship with the content of tannins and associated polyphenols. *Journal of Agriculture and Food Chemistry, 30*(3), 734–739.

Gallegos-Infante, J. A., Rocha-Guzman, N. E., Gonzalez-Laredo, R. F., Pulido-Alonso, J. (2009). Effect of processing on the antioxidant properties of extracts from a Mexican barley (*Hordeum vulgare*) cultivar. *Food Chemistry*. doi:10.1016/j.foodchem.2009.07.044.

Gamez, E. J. C., Luyengi, L., Lee, S. K., Zhu, L., Zhou, B., Fong, H. H., et al. (1998). Antioxidant flavonoid glycosides from *Daphniphyllorum calycinum*. *Journal of Natural Products, 61*(5), 706–708.

Garcia-Baños, J. L., Corzo, N., Sanz, M. L., & Olano, A. (2004). Maltulose and furosine as indicators of quality of pasta products. *Food Chemistry, 88*(1), 35–38.

Geil, P. B., & Anderson, J. W. (1994). Nutrition and health implications of dry beans: A review. *Journal of the American College of Nutrition, 13*(6), 549–558.

Giese, J. (1992). Pasta: New twists on an old product. *Food Technology, 46*(2), 118–126.

Gowen, A. A., Abu-Ghannam, N., Frias, J. M., & Oliveira, J. C. (2007). Characteristics of cooked chickpeas and soybeans during combined microwave – Convective hot air drying. *Journal of Food Processing and Preservation, 31*(3), 433–453.

Granito, M., Guerra, M., Torres, A., & Guinand, J. (2004). Efecto del procesamiento sobre las propiedades funcionales de *Vigna sinensis*. *Interciencia, 29*(9), 521–526.

Granito, M., Torres, A., & Guerra, M. (2003). Desarrollo y evaluación de una pasta a base de trigo, maíz, yuca y frijol. *Interciencia, 28*(7), 372–379.

Guerra-Hernandez, E., Corzo, N., & Garcia-Villanova, B. (1999). Maillard reaction evaluation by furosine determination during infant cereal processing. *Journal of Cereal Science, 29*(1), 171–176.

Hernández-Nava, R. G., Berrios, J. De J., Pan, J., Osorio-Díaz, P., & Bello-Perez, L. A. (2009). Development and characterization of spaghetti with high resistant starch content supplemented with banana starch. *Food Science and Technology International, 15*(1), 73–78.

Hoseney, C. (1999). *Principles of cereal science and technology* (pp. 269–274). St. Paul, MN, USA: American Association of Cereal Chemists.

Jiratavan, T., & Liu, R. H. (2004). Antioxidant activity of processed table beets (*Beta vulgaris*) var conditiva and green beans (*Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry, 52*(12), 2659–2670.

Knuckles, B. E., Hudson, C. A., Chiu, M. M., & Sayre, R. N. (1997). Effect of β-glucan barley fractions in high fiber bread and pasta. *Cereal Foods World, 42*(1), 94–99.

Köber, E., Gonzalez, M. E., Gavioli, N., & Salmoral, E. M. (2007). Modification of water absorption capacity of a plastic based on bean protein using gamma irradiated starches as additives. *Radiation Physics and Chemistry, 76*(1), 56–60.

Malcolmson, L. J., Matsuo, R. R., & Balshaw, R. (1993). Textural optimization of spaghetti using response surface methodology: Effects of drying temperature and durum protein level. *Cereal Chemistry, 70*(4), 417–423.

Marconi, E., & Carcea, M. (2001). Pasta from non traditional raw materials. *Cereal Foods World, 46*(11), 522–529.

Osorio-Diaz, P., Aguilar-Sandoval, A., Agama-Acevedo, E., Rendón-Villalobos, R., Tovar, J., & Bello-Perez, L. A. (2008). Composite durum wheat flour/plantain starch digestibility, and indigestible fraction content. *Cereal Chemistry, 85*(3), 339–343.

Ovando-Martinez, M., Sayago-Ayerdi, S., Agama-Acevedo, E., Goñi, I., & Bello-Perez, L. A. (2009). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chemistry, 113*(1), 121–126.

Ramirez-Jimenez, A., Guerra-Hernández, E., & Garcia-Villanova, B. (2003). Evolution of non-enzymatic browning during storage of infant rice cereal. *Food Chemistry, 83*(2), 219–225.

Rayas-Duarte, P., Mock, C. M., & Saterlee, L. D. (1996). Quality of spaghetti containing buckwheat, amaranth and lupin flours. *Cereal Chemistry, 73*(2), 381–387.

Rendón-Villalobos, R., Osorio-Diaz, P., Agama-Acevedo, E., Tovar, J., & Bello-Perez, L. A. (2008). Composite wheat-plantain starch salted noodles. Preparation, proximal composition and in vitro starch digestibility. *Interciencia, 33*(9), 658–662.

Resmini, P., Pagani, M. A., & Pellegrino, L. (1990). Valutazione del danno termico nella pasta alimentare mediante determinazione per HPLC della furoilmetil-lisina (furosina). *Tecnica Molitoria, 10*(5), 821–826.

Rocha-Guzmán, N. E., Gallegos-Infante, J. A., González-Laredo, R. F., Bello-Pérez, L. A., Delgado-Licon, E., & Ortiz-Prado, M. J. (2008). Physical properties of extruded products made with three Mexican common beans (*Phaseolus vulgaris* L.). *Plant Foods for Human Nutrition, 63*(3), 99–104.

Rocha-Guzman, N. E., Gonzalez-Laredo, R. F., Ibarra-Perez, F. J., Nava-Berumen, C. A., & Gallegos-Infante, J. A. (2007). Effect of pressure cooking on the antioxidant activity of extracts from three common bean (*Phaseolus vulgaris* L.) cultivars. *Food Chemistry, 100*(1), 31–35.

Setiady, D., Lin, M., Younce, F., & Rasco, B. A. (2007). Incorporation of minced trout (*Onchorhynchus mykiss*) into egg-based noodles. *Journal of Food Processing and Preservation, 31*(4), 480–491.

Shelke, K. (2006). Pasta passion: High-antioxidant, organic, whole-grain and multi-grain pasta products are redefining the category. *Food Processing,* February 1, retrieved August 8, 2009 from: <http://www.allbusiness.com/manufacturing/food-manufacturing/873584-1.html>.

Tudorica, C. M., Kuri, V., & Brennan, C. S. (2002). Nutritional and physicochemical characteristics of dietary fiber enriched pasta. *Journal of Agricultural and Food Chemistry, 50*(2), 347–356.

Verzelloni, E., Tagliazucchi, D., & Conte, A. (2007). Relationship between the antioxidant properties and the phenolic and flavonoid content in traditional balsamic vinegar. *Food Chemistry, 105*(3), 564–571.

Villenueve, S., & Gelinas, P. (2007). Drying kinetics of whole durum wheat pasta according to temperature and relative humidity. *Food Science and Technology – LWT, 40*(3), 465–471.

Xu, G., Ye, X., Chen, J., & Liu, D. (2007). Effect of heat treatment on the phenolic compounds and antioxidant capacity of citrus peel extract. *Journal of Agricultural and Food Chemistry, 55*(2), 330–335.

Yoshimura, Y., Iijima, T., Watanabe, T., & Nakazawa, H. (1997). Antioxidative effect of Maillard reaction products using glucose – Glycine model system. *Journal of Agricultural and Food Chemistry, 45*(10), 4106–4109.

Zhao, Y., Manthey, F., Chang, S., & Yuan, S. (2005). Quality characteristics of spaghetti as affected by green and yellow pea, lentil and chickpea flours. *Journal of Food Science, 70*(3), S371–S376.