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Comparative study of the partial replacement of *Triticum durum* semolina in *fettuccine* pasta by bamboo fiber and young bamboo culm flour

Estudo comparativo do uso de fibra de bambu e farinha do colmo jovem de bambu na produção de massas alimentícias de semolina de *Triticum durum*

Estudio comparativo del uso de fibra de bambú y harina de culmo de bambú joven en la producción de pasta de sémola a partir de *Triticum durum*

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Abstract
A comparative study was carried out with the partial replacement of *Triticum durum* semolina in fettuccine pasta with bamboo fiber (BF) and young bamboo culm flour (YBCF) regarding the consumer demand for healthier products and the inconvenience of using wheat bran in whole-grain pasta. Through a 2² central rotation composite design (CCRD), with five trials at the central point, totalling 13 essays (P1-P13) with independent variables X (0% to 3.5% of BF) and Y (YBCF) (0% to 3.5% of semolina substitution). There was no significant effect of the variables on optimal cooking time (OCT), mass gain (MG), volume increase (VI), loss of soluble solids (LSS), and force to cut of samples, although there was an increase in the color parameters L* and a*. Pasta P7, P8, and P10 showed average scores in sensory analysis within the region of acceptance as a control pasta. Therefore, it was possible to use YBCF in pasta production, suggesting a balance in managing bamboo clumps.
Key words: Pasta; Fiber; Health; Sustainability; Gramineae.

Resumo
Aliando a busca dos consumidores por produtos mais saudáveis e o inconveniente da utilização do farelo de trigo em massas alimentícias integrais, foi realizado o estudo comparativo com a substituição parcial de semolina de *Triticum durum* em massas alimentícias do tipo *fettuccine* por fibra de bambu (BF) e farinha de colmo jovem do bambu (YBCF). Através de delineamento central composto rotacional 2², com cinco repetições no ponto central, totalizando 13 ensaios (P1-P13) com variáveis independentes X (0% a 3,5% de BF) e Y (YBCF) (0% a 3,5% de substituição da semolina) e uma massa controle, com 100% de semolina. Não houve efeito significativo das variáveis sobre TOC, GM, AV, PSS e firmeza dos ensaios. Houve aumento dos parâmetros de cor L* e a*. Amostras de P7, P8 e P10 apresentaram médias de notas em análise sensorial dentro da região de aceitação e semelhante à controle. Assim, foi possível utilizar YBCF na produção de massas alimentícias, sugerindo equilíbrio no manejo de touceiras de bambu.
Palavras-chave: Massa alimentícia; Fibras; Saudabilidade; Sustentabilidade; Gramineae.

Resumen
Combinando la demanda de los consumidores por productos más saludables y la inconveniencia de usar salvado de trigo en la pasta integral, se realizó un estudio comparativo con el reemplazo parcial de sémola de *Triticum durum* en pasta fettuccine por fibra de bambú (BF) y harina de talo de bambú joven (YBCF). Mediante un diseño central compuesto rotacional 2², con cinco repeticiones en el punto central, totalizando 13 pruebas (P1-P13) con variables independientes X (BF) e Y (YBCF) (0% a 3.5% de sustitución de sémola) e una pasta control, con 100% de sémola. No hubo efecto significativo de las variables sobre TOC, GM, AV, PSS y firmeza de las pruebas. Hubo un aumento en los parámetros de color L* y a*. Las muestras de P7, P8 y P10 mostraron puntuaciones medias en el análisis sensorial dentro de la región de aceptación e similar à control. Por lo tanto, es posible utilizar YBCF en la producción de pasta, lo que sugiere un equilibrio en el manejo de las matas de bambú.
Palabras clave: Pasta; Fibras; Salubridad; Sostenibilidad; Gramineae.

1. Introduction

In 2019, the world produced 16,500 tons of pasta and Italy, Tunisia and Venezuela were the largest consumers of this product (IPO, 2021). Traditionally, pasta is produced from mixing semolina from Triticum durum and water but depending on the availability or not of T. durum and according to market desires, the ingredients can be changed, such as the production of whole grain or even gluten-free pasta for example.

In countries where there is no domestic production of *T. durum*, the import of semolina is the solution to serve the domestic pasta market, directly affecting its economy. One way to avoid the need for imports and to encourage the local economy may be the incorporation of other regional ingredients, which can help in the economy and increase the healthiness of the pasta. There is still no official data on the production and commercialization of wholesome pasta globally, neither tracking of the consumption of pasta with the incorporation of local ingredients, but consumer demand for healthier products has been growing year by year (Brasil Food Trends, 2014).

In addition to the economic importance of pasta, they are mostly consumed as a main meal. Due to the characteristics of *T. durum* semolina, such as yellowish color, content of gluten-forming proteins, and the rheological profile, it is adequate for the preparation of pasta, allowed the incorporation of other ingredients on its matrix without the loss of quality in pasta (Kill Turnbull, 2001).

Knowledge and the search for quality of life and better eating habits influence the choice of products. People are likely to choose those similar to conventional products, not forgetting the benefits for health or substances that contribute to an improvement in health and well-being, as if deals with the use of new fibers, including bamboo.

Some cultures, such as Asia, have the habit of using bamboo both in food and in the therapeutic area (Nongdam; Tikendra, 2014). Bamboo fibers present high nutrient content, functionality as nutraceuticals, in addition to a pleasant taste, and negligible energy value (Chongtham et al., 2011).

Felisberto et al. (2017) produced and analyzed bamboo flours from the young culm of three varieties: *Dendrocalamus asper*, *Bambusa tuldoides*, and *Bambusa vulgaris*. Flours showed differences in their content of carbohydrates, especially regarding dietary fiber and starch contents. Due to these differences, the authors pointed out that the three species have the potential for fiber extraction, with levels greater than 60 g/100 g. In addition, all the flours showed light yellow color, which confirms their potential application as an ingredient in the food industry.

In another study, Felisberto et al. (2021) evaluated different portions of the young culm (bottom, middle and top) of the same three varieties of bamboo, looking for their fibrous fractions (79-89%), which were obtained after starch extraction. The fractions showed a light-yellow color, with n high L* parameter ranged 80-90. As for its composition, the fractions of *B. tuldoides* presented fiber content between 85.15 g/100 g and 87.07 g/100 g, and the monosaccharides present in greater concentration were arabinoses and xyloses. Through NMR analysis, the presence of xylans and arabinoxylans was also observed.

The high fiber content found in young bamboo culm flours is vital for its use in food products., since dietary fibers are non-digestible carbohydrate fractions with different functions in the human body, such as increased intestinal motility and satiety effect. Furthermore, the importance of fibers in preventing chronic non-communicable diseases has also been reported in the literature (Kaczmarczyk et al., 2012). Among the flours available on the market, the fiber content and composition differ depending on the raw material, as well as its origin or harvest. Wheat flour fiber content, for example, can vary from 10.7 to 15.5% (Gebruers et al., 2008).

The search for new natural ingredients has been stimulated, as the development of food products must be inserted within the concepts of healthiness and well-being, in addition to sustainability and ethics, reliability, and quality, as presented in Brazil Food Trends 2020 (2010). Kruger et al. (1998) related the presence of bran and whole flours with negative perception by the consumer, and for this reason the incorporation of fibers in food products has been a great challenge.

Ferreira et al. (2021) evaluated fettuccine-type pasta produced with the partial replacement of semolina from *Triticum durum* by commercial light fibers. The authors demonstrated that the use of commercial bamboo fiber and wheat fiber in amounts of up to 7.5% replacement did not negatively alter the technological characteristics of the pasta.

We believe that pasta could promote sustainability in developing countries with the use of local fibers, in food products or not, valuing the raw material and encouraging healthiness, and increasing food satiety go in the exact direction of consumer search. In this way, seeking to obtain food products enriched with fibers, and without the problems of using bran, white fibers can be used as ingredients, offering healthier products with the same characteristics desired by the consumer. The objective of this work was to compare the technological characteristics of dry fettuccine pasta formulated with partial replacement of *T. durum* semolina by commercial bamboo fiber and young bamboo culm fiber from *B. tuldoides* variety (YBCF).

2. Metodology

The *T. durum* semolina was provided by Pastificio Selmi S/A (Sumaré, SP). The commercial bamboo fiber BF (CREAFIBE QC90) was provided by Nutrassim Indústria, Comércio, Importação e Exportação Ltda. (Extrema, MG) and the young bamboo culm fiber (YBCF) was developed in the laboratory by Felisberto et al. (2017) and assigned to the present study.

In Figure 1, we can see the raw materials used in the study. Semolina, Commercial bamboo fiber (BF), young bamboo culm flour (YBCF).

Figure 1: Raw materials used in the production of pasta with fibers. Where: BF = commercial bamboo fiber and YBCF = young bamboo culm flour.

Source: Authors.

2.1 Characterization of raw materials

The semolina used was rheologically evaluated by extensography, farinography, number of falls, and gluten index according to methods of the International Association of Cereal Chemistry (2010); and its proximate composition was carried out following the official methods for determining the moisture, protein, lipid, ash (AACCI, 2010) and dietary fiber content

(Association of Official Analytical Chemists, 2006). Total carbohydrates were calculated by the difference. The moisture content of the commercial bamboo fiber was determined using the same method as semolina, and the manufacturer provided the fiber content specification. The raw materials were also evaluated, using the CIELab system, by color parameters L*, a*, and b*, through the MiniScan XE 3500 colorimeter (Hunterlab, Reston, Virginia, USA).

2.2 Experimental design

A factorial design with two variables (BF and YBCF), axial points and five replicates at the central point was used, totaling 13 tests. The construction of the design matrix, all stages of analysis of the response surfaces and the results were conducted according to Rodrigues and Iemma (2014). Table 1 shows the CCRD matrix with coded and decoded variables.

Table 1. Matrix of the central composite rotational design (CCRD) with coded variables (X and Y) and absolute values of commercial bamboo fiber (BF) and young bamboo culm flour (YBCF) for the 13 studied formulations.

Pasta	Coded values		Absolute values		Semolina
	X (BF)	Y (YBCF)	BF	YBCF	q.s.p.*
P1	-1	-1	0.51	0.51	98.98
P2	1	-1	2.99	051	96.50
P3	-1	1	0.51	2.99	96.50
P4	1	1	2.99	2.99	94.02
P5	-1.41	0	0	1.75	98.25
P6	1.41	0	3.50	1.75	94.75
P7	0	-1.41	1.75	0	98.25
P8	0	1.41	1.75	3.50	94.75
P9	0	0	1.75	1.75	96.50
P10	0	0	1.75	1.75	96.50
P11	0	0	1.75	1.75	96.50
P12	0	0	1.75	1.75	96.50
P13	0	0	1.75	1.75	96.50

* q.s.p = enough amount to reach 100%. Source: Authors.

2.3 Pasta production

The dry ingredients were mixed in Pastaia (Italvisa) in 500 g batches of semolina and fiber premix. Water (33 g/100 g premix for control and 40 g/100 g premix for the other tests) was added slowly over 2 min. It was mixed for 13 min, and the pasta remained at rest for 5 min. Cold extrusion was performed using a ribbon-shaped die, and the doughs were cut to 30 cm, giving rise to long fettuccine type pasta. After, the drying was carried out in an oven with forced air circulation, at 55 °C, until reaching a moisture content below 13%. In the end, the dry pasta was packed in polyethylene bags, hermetically sealed, and stored.

2.4 Technological assessment

The optimal cooking time (OCT), weight gain (WG), volume increase (VI), and loss of soluble solids (LSS) during cooking were determined in cooked pasta, according to the AACCI methodology (2010), as well as the force needed to cut the dough after cooking (FC – force to cut), which was performed in a Stable Micro-System Texturometer, model TA-XT2i (Surrey, UK), using probe knife blade (A/LKB).

The color parameters were evaluated on raw and cooked pasta on an opaque white background, using the CIELab system, with a portable colorimeter MiniScan XE from Hunter Associates Laboratory Inc. (Reston, Virginia - USA). Six dough ribbons were analyzed for L*, a*, and b* parameters, with D65 illuminant and 10° observation angle.

2.5 Selection of pasta

Pasta that presented the most similar characteristics to the formulation produced only with water and 100% of semolina (C = control formulation) were selected and carried through a sensory evaluation.

2.6 Scanning Electron Microscopy (SEM)

The samples were also subjected to Scanning Electron Microscopy (SEM), using an LEO-1430 scanning electron microscope at the Institute of Geosciences of the Federal University of Para (UFPA-Brazil). Eight samples of C, P7, P8 and P10 were placed on double-sided adhesive carbon tapes and metalized with a thin layer of gold. The operating conditions were electron beam current of 90 A, accelerating voltage of 20 kV, and working distance of 15 mm.

2.7 Sensory evaluation

Selected pastas were submitted to sensory analysis, carried out at the State University of Campinas - UNICAMP (Campinas, São Paulo, Brazil), and approved by the Research Ethics Committee of this university (CAAE 70882517.4.0000.5404).

Sixty pasta consumers, aged between 18 and 60 years, participated in the analysis. Participants signed the Free and Informed Consent Form. The methodology used was proposed by Meilgaard, Civille, and Carr (2006). The tasters were presented with four raw pasta, monadically, in Styrofoam packaging, identified with a three-digit code and the corresponding form for the sensory evaluation.

To evaluate the cooked pastas, they were prepared by cooking them in boiling water (95 °C) according to OCT specific for each pasta and draining them in sieves, being placed in disposable styrofoam cups. Pasta was identified using random three-digit numeric codes. One sample was presented at a time, accompanied by an evaluation form.

The tasters were asked about the appearance of the product, having to mark the grades according to a 9-point hedonic scale being "1", "I disliked a lot" to "9", "I liked it very much", with the grade as a neutral point "5" "I did not like it, nor did I dislike it". Following the same methodology, we asked the tasters about the color of the product, flavor, aroma, and crispness. Then, according to the overall impression about the product, they were asked to rate it concerning the intention to consume it on a 5-point hedonic scale with "1", "I would certainly not consume" and "5", "I would certainly consume", Having as neutral point "3", "Maybe it would consume, maybe it would not consume".

2.8 Statistical analysis

All analyzes were performed in triplicate. Data were presented as means ± standard deviation and underwent analysis of variance (ANOVA), where significance (p-value) and lack of adjustment of the regression at the 10% confidence level were determined.

For the significant models, the response surfaces were obtained using the Statistica 8.0 software. Those with a significant p-value and non-significant lack of adjustment at the 10% confidence level with an R^2 greater than 0.80 were considered predictive (Barros Neto; Scarminio; Bruns, 2001). The other models that met the first considerations, but had R^2 less than 0.80, were considered trend models.

The statistical analysis of the scores obtained with the 60 tasters for the parameters analyzed in the sensory test was performed from ANOVA analysis of variance by the Scott-Knott test with a significance level ($p \leq 0.05$) using the SISVAR 5.6 program.

3.Results and discussion

3.1 Raw material characterization

The semolina presented a moisture content of 13.47 ± 0.09%, the total dietary fiber content of 5.79 ± 0.65%, and a characteristic yellowish color with color parameters L* 87.17 ± 0.8, a* 1.58 ± 0.04 and b* 20.86 ± 0.59.

The YBCF obtained by Felisberto et al. (2017) presented a moisture content of 3.24 ± 0.20%, 1.57 ± 0.04% of proteins, lipid content under 0.24%, 1.37 ± 0.07% of ash, 1, 23 ± 0.04% of total sugars, and total dietary fiber content of 98.27 ± 0.60%.

3.2 Technological assessment

Table 2 presents the results obtained in the technological analysis of pasta produced according to the proposed design and, in Table 3, the analysis of variance for the parameters and statistical effects found can be observed. From Table 2, the OCT values ranged between 12.5 and 13.5 min. According to Gatta et al. (2017), the incorporation of fiber in pasta causes changes in OCT. It is not possible to establish a constant effect since different fiber sources bring different effects on OCT, which can be increased or reduced. The mass gain was between 2.21 times and 2.80 times. For the volume increase parameter, the variation was between 2.92 times and 3.56 times. The loss of solids ranged between 5.06g/100g of pasta and 9.14g/100g, while the cutting force was between 8.70N and 16.70N. All the pasta showed a light-yellow color.

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Table 2. Results of technological analysis of the pasta obtained from the central rotational composite design (CCRD) in cooking test[a] and color parameters of the dry and cooked pasta.

Pasta	**OCT[b] (min)**	**Mass gain**	**Volume increase**	**Loss of soluble solids (g/100g)**	**Force to cut (N)**	**Color parameters**					
						Dry pasta			**Cooked pasta**		
						L*	**a***	**b***	**L***	**a***	**b***
P1	12.5	2.51±0.16	3.44±0.77	9.03±1.32	9.19±2.23	64.97±1.63	0.18±0.26	28.66±1.88	77.38±0.78	-2.90±0.10	24.23±1.83
P2	13	2.36±0.10	3.56±0.51	9.10±0.37	10.08±1.84	73.14±0.24	0.29±0.05	34.22±0.83	77.57±1.45	-3.18±0.19	22.21±0.65
P3	12.5	2.25±0.15	2.92±0.14	7.42±0.02	9.54±4.62	71.51±1.34	1.92±0.44	27.57±4.07	75.52±0.15	-1.90±0.19	21.36±1.24
P4	13	2.21±0.06	3.22±0.38	5.48±0.06	8.70±3.51	74.79±1.10	1.52±0.47	25.64±6.97	76.78±0.60	-1.42±0.26	24.90±0.89
P5	13.5	2.48±0.22	3.33±0.14	9.14±0.47	9.22±3.64	72.61±0.82	1.55±0.30	32.93±2.20	76.19±1.04	-2.58±0.11	22.54±0.64
P6	13.5	2.58±0.14	3.22±0.38	6.18±0.11	10.89±2.64	74.89±0.52	1.36±0.24	35.30±0.40	76.30±0.93	-2.76±0.15	21.62±2.05
P7	13.0	2.80±0.09	3.42±0.14	4.88±0.10	12.50±0.76	74.66±0.42	0.74±0.24	36.14±1.38	78.34±0.90	-3.38±0.17	23.64±1.07
P8	13.0	2.54±0.18	3.25±0.25	5.06±0.03	14.51±4.08	72.88±0.27	1.70±0.19	30.21±1.12	77.01±1.00	-2.07±0.14	22.92±0.71
P9	13.0	2.38±0.04	3.00±0.00	5.29±0.03	15.07±2.66	74.76±1.47	0.91±0.41	26.61±9.11	76.52±1.06	-2.97±0.10	22.18±0.84
P10	13.0	2.52±0.16	3.17±0.14	5.44±0.06	15.24±2.69	72.47±1.11	1.42±0.10	34.05±0.69	77.53±0.52	-2.73±0.09	23.78±0.66
P11	12.5	2.47±0.06	3.08±0.14	5.01±0.11	16.70±3.26	71.43±0.41	2.08±0.13	33.34±0.84	76.14±0.36	-2.18±0.19	24.04±1.20
P12	13.0	2.46±0.11	3.17±0.14	5.79±0.03	16.61±1.72	70.63±0.90	0.86±0.17	28.08±1.86	77.29±0.40	-2.39±0.10	22.48±1.14
P13	13.0	2.72±0.09	3.17±0.14	5.33±0.02	15.94±2.00	72.73±0.14	1.11±0.07	33.08±0.55	77.43±1.23	-2.74±0.32	22.98±1.11

[a] Results expressed by mean ± standard deviation [b] OCT = Optimal cooking time. Source: Authors.

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Table 3. Analysis of variance table (ANOVA) for the response surface of the technological characteristics of the pasta obtained through CCRD[a].

Parameters		**Mathematical model**	**Mean±standard deviation**	**R^2**	**p-value (<0,10)**	**Lack of fit[1]**	**Square mean pure error**	**$F_{calculated}$**	**F_{table}**
Raw pasta									
Color	**L***	ns	72.40±2.79	0.32	0.0428	6.69	2.43	5.24	3.18
	a*	$a^*_{raw} = 1.20+0.541x$		0.57	0.0030	0.11	0.25	14.36	3.18
	b*	ns	31.22±3.02	0.41	0.0000	0.13	11.72	0.52	3.18
Cooked pasta									
OCT (min)		ns	12.96±1.7	0.33	0.0000	0.21	0.05	0.42	3.18
LSS		$LSS = 5.48025-0.757242x+1.4936x^2$		0.61	0.0094	2.13	0.08	7.72	3.18
VI		$VI= 3.1689-0.137423y+0.093808y^2$		0.55	0.0174	0.02	0.01	6.24	3.18
WG		ns	2.48±0.9	0.31	0.0000	0.05	0.02	0.07	3.18
FC		$FC = 15.91766-3.54686x^2-1.81153y^2$		0.84	0.0001	2.61	0.56	27.80	3.18
Color	**L***	$L^* =76.92394-0.56695y$		0.36	0.0297	0.43	0.38	6.23	3.18
	a*	$a^* = -2.55393+0.57772y$		0.74	0.0002	0.08	0.10	31.81	3.18
	b*	$b^* = 22.99+1.39xy$		0.57	0.0029	0.47	0.65	14.50	3.18

[a] CCRD = Central composite rotational design. ns = not significant. Optimal cooking time (OCT), weight gain (WG), volume increase (VI), force to cut (FC). Source: Authors.

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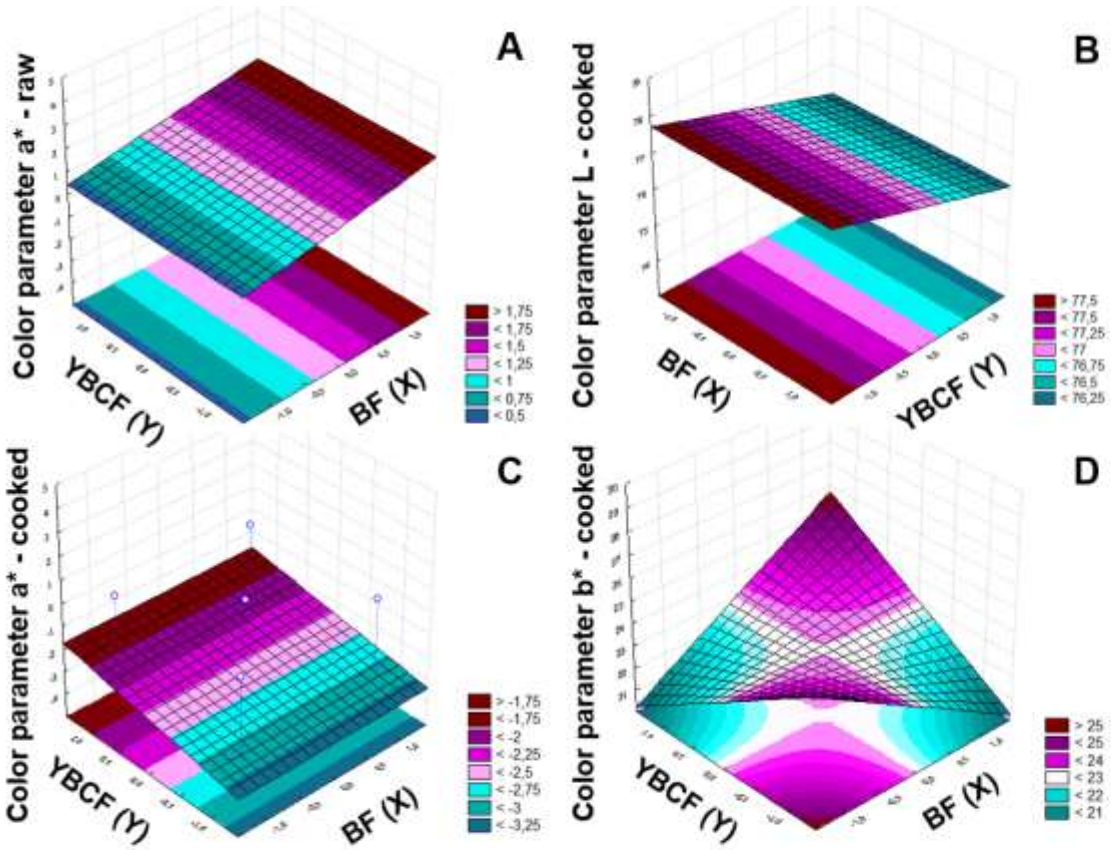
Analyzing the response surfaces for the L*, a*, and b* color parameters of the raw and cooked pasta, in addition to the OCT, LSS, VI, WG, and texture parameters (Table 3 and Figure 2), it was observed that the studied concentrations of replacement of semolina by the two fibers (BF and YBCF) did not significantly influence the OCT and WG parameters.

Figure 2. Response surface for a* color parameters of raw (A) and cooked (C), L* of cooked pasta (B) and b* of cooked pasta (D). Where X=commercial bamboo fiber (BF) and Y= young bamboo culm flour (YBCF).



Source: Authors.

The color parameter L* for raw pasta ranged from 70 to 75, while for cooked pasta, it was higher, ranging from 76 to 77.5. The absorption of water can explain such an increase of the dough, the swelling of the starch granule, and the loss of soluble solids from dough to cooking water. It can be seen in Figures 2A and 2C that BF influenced the a* color parameter of pasta, as the higher BF concentration in formulation, the higher as a* values.

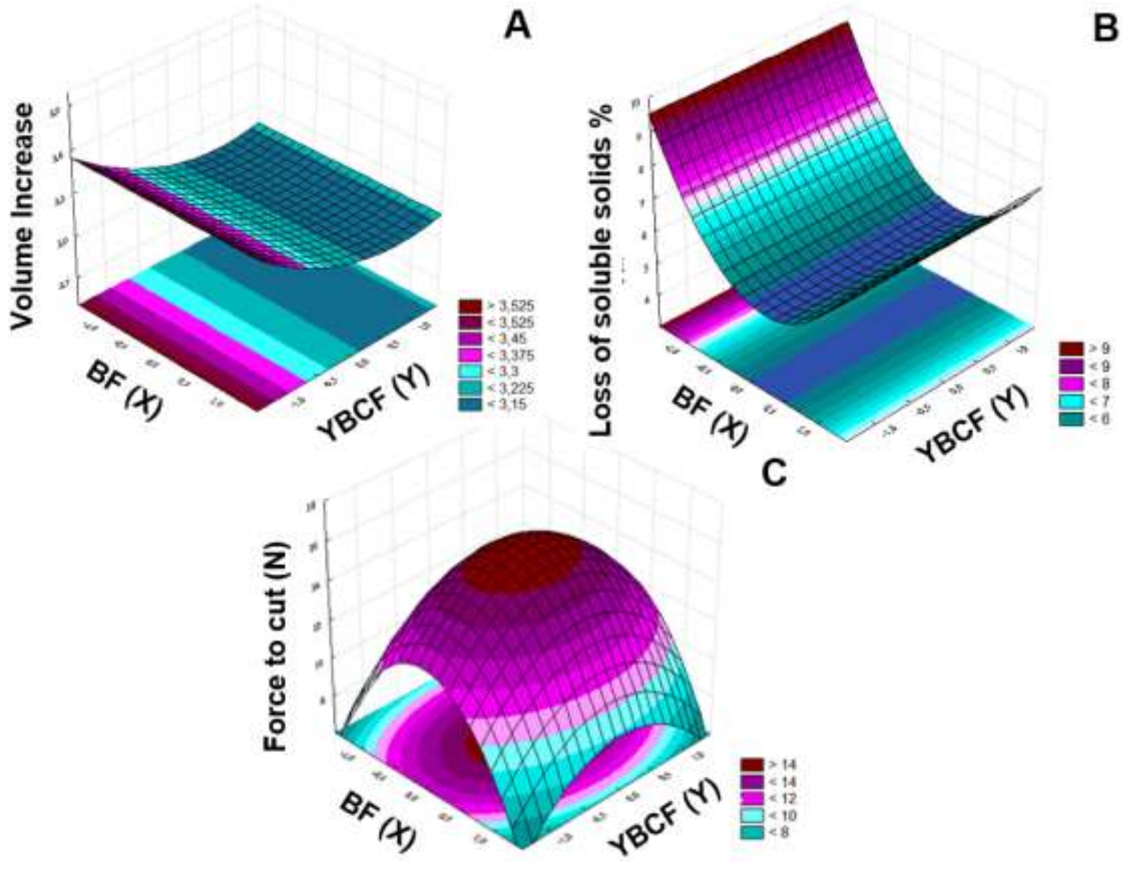
For the L* color parameter, whose response surface is shown in Figures 2 A and C, a significant effect was obtained for the presence of YBCF in pasta. The model is shown in Table 3, and Figure 2B indicates a trend, as $R^2<0.80$, and all L* values were greater than 75, indicating a light pasta. Aravind et al. (2012) evaluated the effects of replacing *T. durum* semolina by 10 to 60% pollard and 10 to 30% wheat bran in the production of dry and long pasta and also noted that pasta with high fiber content (added bran) showed a significant reduction in color parameters L* and b* to control.

For the parameter a* of the color of the cooked pasta, a trend model was obtained ($R^2<0.80$) (Table 3). For the parameter a* of the raw pasta, it was verified through the response surface (Figure 2A) that the BF concentration influenced this color parameter the most, and in the cooked pasta, it was the YBCF concentration that had a trend ($R^2<0.80$) (Table 3) in the increase of a* values. Vignola, Bustos, and Pérez (2017) compared the quality attributes of pasta produced from refined wheat flour and whole-grain wheat flour and found values between 1.9 and 2.5 of a* for the pasta produced of refined flour, and values between 6.1 and 8.2 in the pasta produced from whole-grain wheat flour.

In Figure 2D, the response surface graph for the b* color parameter of the cooked pasta can also be seen positive values of b*, that is, yellow-colored pasta. However, a trend (R^2<0.80) showed that when fibers were used together, BF and YBCF resulted in pasta with higher values of b*.

Ciccoritti et al. (2017) evaluated the use of bran and frayed grains of *T. durum* to develop pasta with appeals of healthiness and observed that the pasta with bran fractions and worn grains showed lower b* values than the control pasta (only with semolina), resulting in a less yellowish pasta than the control, with a more brownish color, a result expected due to the color of the bran. Analyzing the response surface for the parameter increase in the volume of cooked pasta (Figure 3A), it was found that it ranged from 3.2 to 3.5, being higher for the lower content of YBCF.

Figure 3. Response surface for the parameters (A) increase in volume, (B) loss of solids and (C) force to cut of the cooked pasta. Where X= commercial bamboo fiber (BF) and Y= young bamboo culm flour (YBCF).



Source: Authors.

Tudorica Kuri and Brennan (2002) studied the effects of replacing *T. durum* semolina with different fibers to produce long pasta. They evaluated the replacement of 7.5%, 10%, and 12.5% substitution by pea fiber and inulin and 3, 5, 7, and 10% substitution of gum guar. The authors observed that pasta with guar gum presented an increase in volume than the control pasta, while pasta with inulin and pea fiber showed no difference to the control for this parameter. The incorporation of pea fiber and inulin increased the LSS during pasta cooking. It can be seen from the response surface (Figure 3B) that the tests performed at the central point (1.75% of replacement of semolina by bamboo fiber and 1.75% of semolina by YBCF) showed the lowest LSS, while the highest-fiber replacement values increased LSS.

Foschia et al. (2015) evaluated the effect of replacing *T. durum* semolina in long spaghetti-type pasta at 5% fiber contents when added separately and 7.5% of each fiber when two of them were added together. The fibers used in the study were long-chain inulin, short-chain inulin, glucagel, psyllium fiber, and oatmeal. The authors observed that pasta produced from all fiber replacements presented OCT greater than the control pasta, and for all pasta, the LSS was more significant than the control, increasing proportionally with the level of semolina substitution. For the pasta with oat flour, a mixture of glucagel and oat flour, glucagel, and psyllium, the LSS was below 8 g/100 g of sample. It was found that the response surface for the pasta cutting force parameter (Figure 3C) increased at the central points; that is, with the use of BF and YBCF together, the force required to cut the pasta strand was higher, and when used outside the central point, it was smaller.

Brennan and Tudorica (2007) evaluated the effect of replacing *T. durum* semolina with 2.5%, 5%, 7.5%, and 10% inulin, glucagel, pea fiber, locust gum, xanthan gum, bamboo fiber, and enriched flour with beta-glucan in the production of long spaghetti-type pasta. Pasta with xanthan gum showed a higher swelling index and lower loss of soluble solids than the control pasta. The dough with locust gum and xanthan gum showed greater firmness than the control dough.

3.3 Selection of pasta

Pasta with the best technological characteristics were P7, P8, and P10 (Table 3), as it features a uniform appearance and loss of soluble solids below 8%.

3.4 Scanning Electron Microscopy (SEM) of selected pasta

It is observed through the images obtained by SEM (Figure 4) that the control paste, both raw and cooked, presented a continuous matrix of protein and with starch inserted inside it. Still for the control formulation, we observed that when cooked it presented the gelatinized starch adhering to the gluten network forming a smooth and continuous surface. In the other pasta, P7, P8 and P10, it can be seen that the fibers (soluble and insoluble) are present and are not completely inserted into the gluten network, and especially close to the insoluble fibers (present in P8 and P10), there are points of network discontinuity (indicative arrows in figure 4) where we notice that the starch is not completely adhered to the network. This is due to the greater difficulty in inserting the fibers into the gluten and starch network. Thus, P7 presents a better appearance in the formation of the paste, in relation to P8 and P10, both for raw and cooked pasta.

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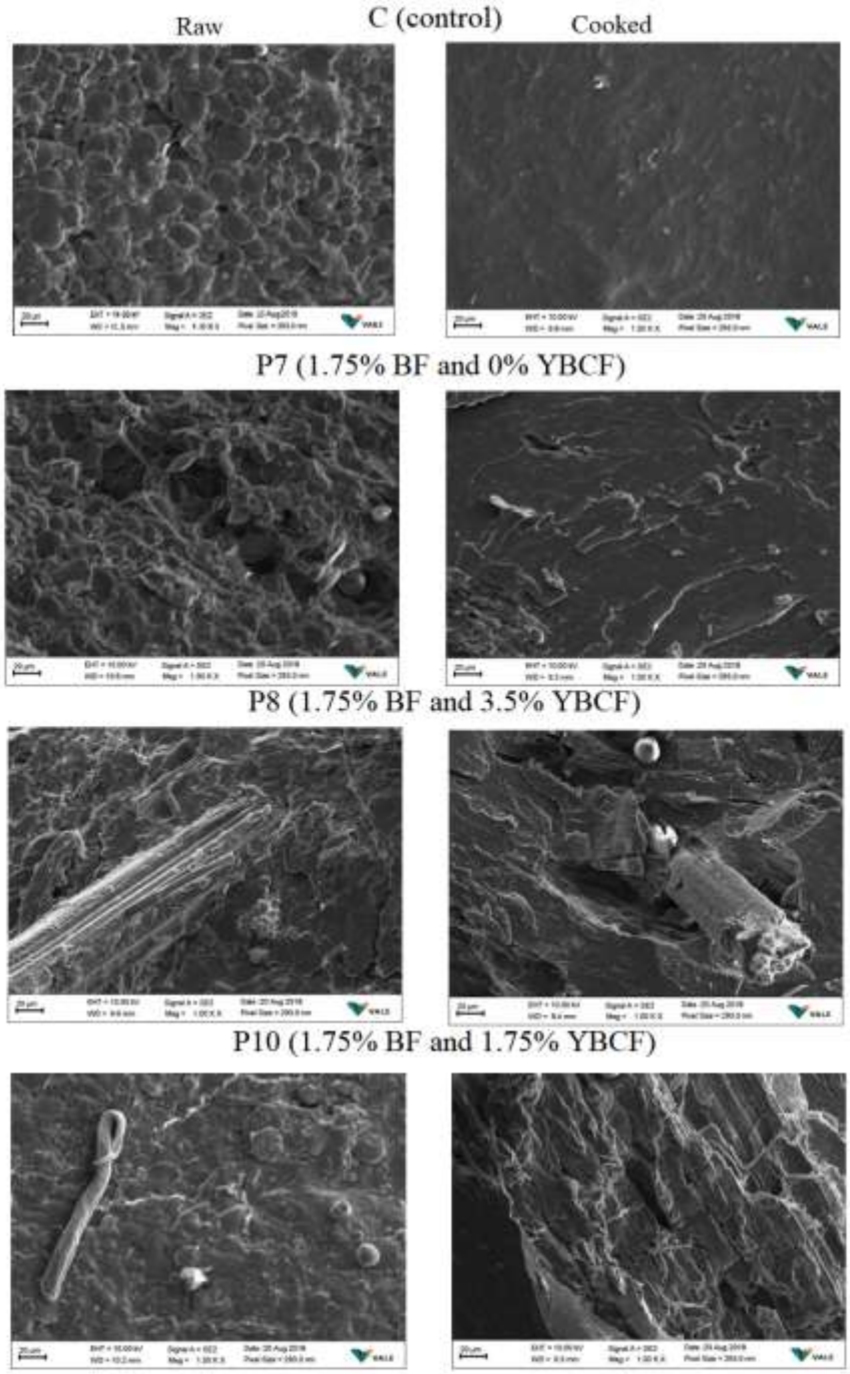
Figure 4. Scanning Electron Microscopy (SEM) of cooked and raw pasta. Where: control pasta (C), P7 (1.75% Bamboo Fiber (BF) and 0% Young Bamboo Culm Flour (YBCF)), P8 (1.75% BF and 3.5% YBCF) and P10 (1.75% BF and 1.75% YBCF).



Where: BF = commercial bamboo fiber; YBCF = young bamboo culm flour. Source: Authors.

3.5 Sensory evaluation of selected pasta

For the sensory evaluation, according to the results, the pasta with the best technological characteristics was P7 (1.75% BF and 0% YBCF), P8 (1.75% BF and 3.5% YBCF), and P10 (1.75% BF and 1.75% YBCF) (Table 3), in addition to a control formulation (C) that contained 100% *T. durum* semolina. Therefore, they were selected and submitted to sensory analysis through an acceptance and consumption intention test, together with a control pasta obtained only with semolina and water.

Table 4 presents the averages of the acceptance grades attributed by the tasters in the sensory analysis for the attributes appearance, color, aroma, flavor, texture, and consumption intention of the control pasta obtained only with semolina and water (C), P7, P8, and P10.

Table 4. Scores obtained in the acceptance and consumption intention test of cooked *fettuccine*-type dry pasta [a].

	Attributes	**C**	**P7**	**P8**	**P10**
Affective test (1-9)	**Appearance**	7.03±1.59[b]	7.56±1.32[a]	7.31±1.33[a]	6.82±1.94[b]
	Color	6.87±1.64[ns]	7.19±1.55[ns]	7.22±1.43[ns]	6.83±1.75[ns]
	Flavor	7.25±1.39[ns]	7.22±1.46[ns]	6.96±1.53[ns]	6.67±1.64[ns]
	Taste	7.10±1.54[a]	7.22±1.39[a]	6.47±1.76[b]	6.11±1.82[b]
	Texture	7.25±1.68[a]	7.30±1.46[a]	6.24±2.10[b]	5.87±2.28[b]
Intention-to-buy (1-5)		3.66±1.03[a]	3.95±0.95[a]	3.29±1.12[b]	3.12±1.22[b]

[a]Results expressed as mean ± standard deviation, different letters on the same line represent a significant difference by the analysis of variance test followed by Scott-Knott ($p<0.05$) and ns = not significant. C=control; P7 = 1.75% BF and 0% YBCF; P8 = 1.75% BF and 3.5% YBCF; and P10 = 1.75% BF and 1.75% YBCF; Notes for affective acceptance test obtained on a 9 cm structured scale, where 5 = neither liked nor disliked; 6 = I liked it slightly and 7 = I liked it regularly; Intent-to-use grades obtained on a 5-cm structured scale, where 2 = probably would not consume; 3 = maybe would not/maybe would; 4 = would likely consume. Source: Authors.

It can be seen, in Table 4, that there was no significant difference between the averages of the scores given by the tasters for the samples in relation to the aroma and color attributes ($p <0.05$), that is, even with the highest levels of fiber replacement, the samples were not statistically different. Color is an essential parameter for pasta, as in this sensory analysis, the pasta was not added with any sauce, unlike what occurs in usual consumption.

West, Seetharaman, and Duizer (2013) evaluated the sensory effects of incorporating whole-grain wheat flour in pasta production. The authors observed that pasta with higher whole-grain flour content had higher values for bitterness, in addition to the perceived flavors of wheat-derived products with higher notes and higher surface roughness for pasta with whole grain and grass flavor.

For the attributes of appearance, flavor, and texture, all evaluated pasta had grades above 5, that is, within the acceptance region. Although a significant difference was found between the average scores for appearance, pasta produced with a higher concentration of YBCF (P8) had higher grades than those produced with the same concentration of bamboo fiber and young bamboo culm flour. This result indicates a possibility of tests with concentrations between 1.75% and 3.5% to find the optimum contents of this substitution so that it does not affect the consumers' perception and allows the greater incorporation of fibers.

The averages of consumer interest were between 3 and 4 ("maybe buy, maybe not buy" and "probably buy"), and the control samples and those from the P7 trial showed no significant difference between them but differed statistically from those referring to the tests P8 and P10. Through these results, it can be inferred that the incorporation of bamboo fiber at the concentration of 1.75% was practically imperceptible for the tasters without having presented a significant difference compared to the control. Therefore, bamboo fiber could be tested on an industrial scale for pasta production and would not cause product rejection.

4. Conclusion

Through the CCRD, it was possible to identify that pasta with the best technological characteristics was obtained with 1.75% bamboo fiber and 3.5% young bamboo culm fiber, and with 1.75% of each fiber. The cooked pasta presented desirable technological characteristics of texture and weight gain, with low solids losses. In the sensory analysis, pasta received grades in the acceptance region. The color of the cooked pasta and texture were affected by the addition of the fibers. Pasta was even sensory accepted, which indicates that both, commercial fiber and that extracted from young culm, presented a potential as a new fiber source to partially replace up to 3.5% of semolina in the production of pastes. For future researches, the application of fibers from shoot and young culm in pasta on an industrial scale, as well as in other cereal-based food products.

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