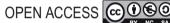# Red pasta: What is the technological impact of the enrichment of beet ingredient in fresh pasta?

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RESEARCH ARTICLE

Abstract

The objective of this study was to evaluate the partial replacement of wheat flour by beet flour (BF) in fresh pasta production, analyzing its chemical, technological, and sensorial characteristics. BF showed good water (4.2 g water/g flour) and oil absorption (2.2 g oil/g flour), water solubility (67.3%), and emulsifying properties (30.0%). The incorporation of BF in fresh pasta formulations improved the nutritional value of the pasta, increased the ash (1.65 to 2.16 g/100g) and fiber contents (1.31 to 12.29 g/100g) of the fresh pasta, and decreased the lipid contents (50.0% reduction), thereby causing changes in its cooking properties. The antioxidant capacity (0.5 to 4.76%) and the content of total phenolics (69.1 to 70.5 mg/100g) and betalains (0.04 to 0.16 mg/100g) also increased with the addition of BF, improving the functional profile of the pasta. In the sensory profile, the pasta formulated with the highest concentrations of BF demonstrated the highest intensities for the sensory attributes among fresh pasta evaluated. In general, it was shown that BF represents a promising ingredient to produce new fresh pasta with functional characteristics.

Keywords: antioxidant activity; betalains; functional product

Introduction

Cereal-based foods are of paramount importance in human nutrition since they represent 30–70% of daily energy intake (Nishida *et al.*, 2004). Pasta is a traditional, cereal-based food, which is very popular worldwide due to its convenience of preparation, nutritional quality, and palatability (Cappa and Alamprese, 2017; Littardi *et al.*, 2020; Tazrart *et al.*, 2019). Pasta is a product of pasting and mechanical kneading, where proteins and starch granules absorb water and lipids to form an emulsion. In kneading, the absence of bubbles is desired because it results in a more compact, resistant, and translucent product.

Triticum durum is commonly used as a raw material for the production of high-quality pasta, as it has characteristics that influence consumer satisfaction, such as culinary properties, color, and aroma (Lee *et al.*, 2002). In Brazil, *T. durum* is not produced and for this reason, 85% of the pasta is produced with common wheat. Thus, adaptations are needed in the formulation of the doughs in order to improve their nutritional and technological quality (Chang and Martínez Flores, 2004).

Pasta can be fresh, dried, instant, and precooked, among others, but in all of these cases, it passes through rolling mills where rolling and cutting is carried out. Most of the fresh pasta consumed is characterized by the presence

of gluten proteins and being a good source of carbohydrates with a low glycemic index (Fradinho *et al.*, 2020; Giménez *et al.*, 2013; Littardi *et al.*, 2020; Sissons *et al.*, 2007). Although fresh pasta is not seen as a nutritionally balanced food or with functional properties due to its low fiber, bioactive contents, and biological protein value, pasta has a high acceptability index and is a fast, versatile, and low-cost food. For this reason, pasta is a good vehicle for nutritional enrichment with the bioactive compound source and can become a functional food (De Santis *et al.*, 2020; Fradinho *et al.*, 2020; Kowalczewski *et al.*, 2019).

Beet (*Beta vulgaris* L.) is a species belonging to the Chenopodiaceae family, rich in minerals, phenolic compounds (including phenolic acids and flavonoids), and betalains (Pandita *et al.*, 2020). Betalains are important red water-soluble pigments in the human diet because they act as antioxidants, combating free radicals and protecting against some diseases related to oxidative stress (Vasconcellos *et al.*, 2016). The production of flours/ingredients from different plant sources is highly encouraged in nutritional enrichment to food development. In this sense, beet flour (BF) has been proposed as an interesting ingredient for the production of innovative and fortified product formulations such as muffins (Seo and Ko, 2014), bread (Lee and Ju, 2016), as well as biscuits (Joo and Kim, 2010) and cookies (Chauhan and Rajput, 2018; Clímaco *et al.*, 2020; Sahni and Shere, 2016). As far as we know, the effect of BF incorporation on the technological properties of fresh pasta or, mainly, BF incorporation with the aim of increasing the concentration of functional components as a strategy to promote a more diverse and nutritious diet has not been studied. Thus, it is necessary to assess whether fresh pasta can be used as a vehicle to promote the functional components present in BF and with good sensory acceptability. Therefore, the objective of this study was to evaluate the partial replacement of wheat flour by BF in fresh pasta production, and evaluate its chemical, technological, and sensorial characteristics.

Material and Methods

Materials and flour production

The beets were collected, washed, and sanitized in sodium hypochlorite solution at 50 ppm, peeled, cut in a Philips Walita RI7762 processor (São Paulo, Brazil), and dried in a convective dryer (Ethik Technology/400-4ND, Botucatu, Brazil) at 60°C for 12 h. The dry product was ground and homogenized on a 20 mesh screen. The ingredients were obtained from the local market: wheat flour (Cristal Alimentos, Goiânia, Brazil), eggs (Ovos Jusidith, Leopoldo de Bulhões, Goiás, Brazil), and salt (Sal Cisne°, São Paulo, Brazil).

Fresh pasta production

The processing of fresh pasta was as described by Lemes *et al.* (2012). Briefly, the standard formulation contained 100% wheat flour, 21.43% eggs, 0.7% salt, and 26.42% water. Wheat flour was replaced with BF in the percentages of 5, 10, and 15. The ingredients were homogenized, and the dough was manually laminated, cut into the "noodle" type, and stored for 24 h under refrigeration (4°C) until analysis.

Chemical characterization

The contents of moisture, lipid (Bligh & Dyer method), protein (conversion factor = 5.75), ash, carbohydrate, and dietary fiber (K-TDFR-Megazyme enzyme kit) were determined according to official Methods (AOAC, 2007). To determine the energy value, the Atwater conversion factors were used based on the proximate composition of the sum of the contents of protein × 4, lipid × 9, and carbohydrate × 4 (AOAC, 2000).

To determine the concentration of betalains in the samples of BF and fresh pasta, a sample (0.2 g) was diluted with distilled water (5 mL) and filtered with a vacuum pump with Whatman filter paper No. 1. The filtrate was read at 536 nm and was performed in triplicate. To quantify the betalain content in the samples, the calculation was used according to the Beer–Lambert–Bouguer Law modified by Tang *et al.* (2007). The content of total phenolic compounds (TPC) was determined according to the method proposed by Singleton and Rossi (1965), modified by Li *et al.* (2009). Antioxidant capacity was measured using the 2,20-azinobis-(3-ethyl-benzothiazoline-6-sulfonic acid (ABTS) method (Miller *et al.*, 1993), modified by Rufino *et al.* (2010); 2,2-difenil-1-picril-hidrazil (DPPH) (Brand-Williams *et al.*, 1995); and the Ferric-reducing antioxidant power (FRAP) method (Benzie and Strain, 1999).

Technological and functional properties of the beet ingredient and fresh pasta

Water absorption index (WAI), water solubility (WS), and oil absorption capacity (OAC) were determined according to the method described by Okezie and Bello (1988). Foaming properties were evaluated according to the method proposed by Coffmann and Garciaj (1977), with modifications. Briefly, the BF (1 g) was mixed with distilled water (50 mL) with vigorous stirring for 5 min, and subsequently transferred to a 100 mL beaker. The volumes were recorded before and after stirring. The foam capacity (FC) index was calculated as the percentage ratio of the increased volume, compared to the initial

volume. Foam stability was determined at 30, 60, 90, and 120 min after formation.

Emulsifying capacity (EC) was evaluated according to Yasumatsu *et al.* (1972), with modifications. The sample (1 g) was mixed with distilled water (10 mL) and soy oil (10 mL). The mixture was stirred in a homogenizer (Q235 Quimis˚, São Paulo, Brazil) for 1 min. After stirring, the emulsions were centrifuged (Novatecnica˚ NT 810, Piracicaba, Brazil) at 5000 ×*g* for 5 min. EC was calculated by dividing the height of the emulsified layer by the total height and expressed as a percentage.

The gel-forming capacity was evaluated according to the method proposed by Coffmann and Garciaj (1977) using concentrations ranging from 2 to 20% of the sample and distilled water (20 mL). The mixtures were placed in a water bath at 90°C for 30 min, cooled in running water for 20 min, and placed in a refrigerator (4°C) for 2 h. Visual observation was performed to detect the presence of gel when inverting the tube.

Pasta was evaluated for cooking characteristics (66-50) (AACC, 2000). Cooking time was the time necessary to reach the point al dente using 20 g of pasta, 2 g of salt, and 200 mL of water. Water absorption was calculated based on an increase of the weight of 20 g of pasta after the cooking process and was expressed in percentage. Volume displacement was evaluated by water volume displacement of 20 g sample after the cooking process. Loss of solids was determined by drying at 105°C the water obtained after cooking of 20 g of fresh pasta. Water retention capacity was determined using 1 g of sample homogenized in 10 mL of water, subjected to heating in a water bath at 80°C for 45 min, and centrifuged at 2000 rpm for 20 min. The results were expressed as a percentage of the increase of weight after water adsorption.

Sensorial analysis: ranking descriptive analysis

A selected and trained sensory panel, consisting of 12 judges, evaluated the four samples using Ranking Descriptive Analysis (RDA). The terms most frequently cited in the assessors' individual list were selected to compose the score sheet for the RDA panel according to the Kelly Network Method (1955) and are presented in Table 1. The assessors defined the attributes and suggested qualitative references based on the samples and other commercial products. Posteriorly, qualitative references were presented and checked by the panel. Finally, the samples were ordered in increasing intensity for each attribute. The repeatability, discrimination, and the homogeneity of judges' scores were checked by a two-way ANOVA after 6 sessions of 1 h each. In the final evaluation, all the fresh pasta formulations were presented simultaneously after cooking and the judge was asked to order in increasing order of intensity each of the previously defined attributes. RDA data were evaluated by Friedman's test (Newell and MacFarlane, 1987) to verify differences between samples for each attribute, considering four samples and the number of final judges (critical value: see table, $P \leq 0.05$). The entire procedure was previously approved by the Research Ethics Committee of Instituto Federal Goiano (CAE 71848117.6.0000.0036).

Table 1. Attributes, definitions, and reference samples for attributes utilized in Ranking Descriptive Analysis (RDA) of fresh pasta.

Attribute	Definition	Reference
Appearance		
Red color	Intensity of color between white and red	WEAK: Santa Amália Speciali Tagliatelle® noodles INTENSE: colored screw pasta
Homogeneous appearance	Absence of lumps or particles visually perceived	WEAK: Renata® noodles homemade-type pasta with hard whole eggs INTENSE: Santa Amália Speciali Tagliatelle® noodles
Aroma		
Egg aroma	Typical beaten egg aroma	WEAK: beaten egg white in snow INTENSE: beaten whole egg
Beet aroma	Typical beet aroma	WEAK: diluted (1:100) beet cooking water INTENSE: cooked beets
Flavor		
Beet flavor	Typical beet flavor	WEAK: diluted (1:100) beet cooking water INTENSE: cooked beets
Sweetness flavor	Sweet taste	NO: water INTENSE: sugar solution 4%
Texture		
Homogeneous texture in the mouth	Absence of lumps or particles perceived in the mouth	WEAK: Renata® homemade noodles with hard whole eggs INTENSE: Santa Amália Speciali Tagliatelle® noodles

Statistical analysis

All analyses were performed in triplicate. The results are presented at the mean ± standard deviation from the mean. The results were analyzed by unilateral analysis of variance (ANOVA), and the Tukey test (P < 0.05) was used to determine differences between means using the Assistat 7.7 software.

Results and Discussions

Beet flour characterization

Table 2 shows the chemical composition of BF and of the fresh pasta incorporated with BF.

The proximal composition of the BF obtained in the present study was comparable to that described in both the legislation and the literature for flour from other vegetable sources: (i) the moisture content of BF (5.67 g/100 g) was lower than the maximum permitted content for wheat flour (15% w/w) (Brasil, 2005; FDA, 2020); (ii) the protein content of BF (9.15 g/100 g) was similar to that found for wheat (~ 9 g/100 g), corn (4–9 g/100 g), and yellow pea (9.9 g/100 g) (Zhao *et al.*, 2019) flours, and higher than that reported for green banana (3.3 g/100 g) (Flores-Silva *et al.*, 2014) and sweet potato (2.89 g/100 g) (Teye *et al.*, 2018) flours; (iii) the lipid content (0.45 g/100 g) was similar to that reported for green banana (0.5 g/100 g) (Flores-Silva *et al.*, 2014), cassava flour (0.79 g/100 g) (Otondi *et al.*, 2020), and sweet potato (0.76 g/100 g) (Teye *et al.*, 2018) flours, and lower than pupunha (7.89 g/100 g) and flaxseed (21.19 g/100 g) (Sakurai *et al.*, 2020) flours; (iv) the ash content that is related to the mineral content of BF (5.62 g/100 g) was higher than that found for green banana (2.4 g/100 g)

(Flores-Silva *et al.*, 2014), manioc and chia (2.59 and 4.98%, respectively) (Otondi *et al.*, 2020), sweet potato (2.19 g/100 g) (Teye *et al.*, 2018), and bean (2.06–3.65 g/100 g) (Rios *et al.*, 2018) flours; (v) the total dietary fiber (21.81 g/100 g) was higher than those reported for sweet potato (3 g/100 g), avocado pear (9.32 g/100 g), and turkey berry (11.13 g/100 g) (Teye *et al.*, 2018) flours; and (vi) the energy value of BF (355.73 kcal) was lower than pumpkin peel (382.54 kcal) (Staichok *et al.*, 2016) and okara (413.92 kcal) (dos Santos *et al.*, 2019) flours. These results demonstrate that BF can contribute to fresh pasta formulations due to its good characteristics nutritional, mainly due to the high value of proteins, fibers, and minerals.

Table 3 shows the technological functional properties of BF. The WAI (4.28 g/g) of the BF was higher than the OAC (2.23 g/g). In comparison with the beetroot waste flour, lower values of water-holding capacity (10.17 g water/g flour) and oil-holding capacity (3.35 g oil/g flour) were observed (Costa *et al.*, 2017). Furthermore, for flour from freeze-dried stems of red beet (*Beta vulgaris* L.), lower values in the present study were also observed in relation to WAI (7.36 to 7.98 g water/g), oil absorption (5.92 to 6.26 g oil/g), and WS index (24.2 to 35.2%) (Wasum and Gurak, 2020). Some studies have demonstrated the impact of drying methods on the production of flour, and it is considered that all flours must undergo the assessment of the best method for its production based on the purpose of its application in the food industry (Guimarães *et al.*, 2020). Despite the higher values observed for freeze-dried BF, it is important to highlight that the choice of processes that result in greater integrity of the raw material but also have lower execution costs can result in greater applicability in the food industry and, therefore, the convective drying process has been widely studied.

Table 2. Chemical composition of beet flour (BF) and fresh paste added 0 (0BF), 5 (5BF), 10 (10BF), and 15 (15BF) percent of BF.

	BF	0BF	5BF	10BF	15BF
Moisture (g/100 g)	5.67 ± 0.04	29.87 ± 0.82[a]	29.19 ± 1.44[a]	29.05 ± 1.82[a]	30.57 ± 0.85[a]
Protein (g/100 g)	9.15 ± 0.62	14.08 ± 0.19[a]	13.83 ± 0.12[a]	13.66 ± 0.29[a]	13.55 ± 0.43[a]
Lipid (g/100 g)	0.45 ± 0.16	4.36 ± 0.04[a]	2.29 ± 0.25[b]	2.44 ± 0.27[b]	2.89 ± 0.08[b]
Ash (g/100 g)	5.62 ± 0.04	1.65 ± 0.02[d]	1.86 ± 0.05[c]	1.95 ± 0.02[b]	2.16 ± 0.01[a]
Total carbohydrate	79.11	50.04	52.83	52.90	50.83
Insoluble fiber (g/100 g)	14.96 ± 0.11	0.94 ± 0.06[c]	1.89 ± 0.53[b]	2.25 ± 0.44[ab]	3.28 ± 0.53[a]
Soluble fiber (g/100 g)	9.01 ± 0.04	0.37 ± 0.17[d]	1.81 ± 0.62[c]	2.27 ± 0.10[b]	9.01 ± 0.04[a]
Energy (kcal)	339.07	290.94	283.63	283,66	265.51
Total betalains (mg/100 g)	0.86 ± 0.02	0.04 ± 0.01[a]	0.14 ± 0.01[b]	0.16 ± 0.03[c]	0.16 ± 0.02[c]
Total phenolic compounds (mg/100g)	88.37 ± 0.28	69.15 ± 0.27[a]	69.89 ± 0.30[b]	70.48 ± 0.17[b]	70.52 ± 0.26[b]
Antioxidant activity (%)	32.07 ± 0.83	0.52 ± 0.17[c]	1.78 ± 0.96[b]	2.06 ± 1.69[b]	4.76 ± 1.58[a]

Table 3. Technological functional properties of beet flour (BF).

Technological functional properties	BF
Water absorption index (WAI) (g water/g flour)	4.28 ± 1.17
Oil absorption capacity (OAC) (g oil/g flour)	2.23 ± 0.20
Water solubility (WS) (%)	67.33 ± 2.31
Emulsifying capacity (EC) (%)	30.00 ± 3.33
Emulsifying stability (%)	22.41 ± 2.51

On the other hand, compared to other vegetable flours, the WAI and OAC of BF were higher than for raw bean flour (2.16 and 1.93 g/g, respectively) (Batista *et al.*, 2010) and for vegetable flours (1.12–1.89 and 0.93–1.38 g/g, respectively) (Du *et al.*, 2014). Meanwhile, the WS of BF (67.33%) was two times higher than for raw and extruded bean flour (33–35%) (Batista *et al.*, 2010), approximately three times higher than for vegetable flours (19.44–29.14%) (Du *et al.*, 2014), and almost seven times higher than for chia flour (9.18%) (Otondi *et al.*, 2020). These parameters are important to define the applicability of new dried ingredients for the food industry. WS index is a parameter that indicates if there were degradation processes suffered by fiber constituents, such as solubilization (Wasum and Gurak, 2020). In addition, high values of WAI and OAC indicate that the flour has the ability to interact with liquid substances, allowing a greater homogeneity of the mixture (dos Santos *et al.*, 2019), favoring its use in processing the most varied food products.

Although the values of emulsifying activity and emulsion stability were lower than those reported by Du *et al.* (2014) for vegetable flours (61.14–88.94 % and 84.15 and 96.90 %, respectively), the results obtained in the present study for the emulsion property and its stability (30.00 and 24.41%, respectively) in BF signal the possibility of its use in meat product formulations such as sausages and hams, for example.

Foam stability decreased over time (10.43, 7.64, 5.56, 1.21, and 0% for 0, 30, 60, 90, and 120 min, respectively), and up to 120 min there was no foam previously formed. The foaming properties of flours depend mainly on the ability of a molecule to form an interfacial film by protein molecules, keeping air bubbles in suspension, and reducing coalescence. The presence of other components, such as carbohydrates in the composition of the flour, also affects its foaming properties (Sreerama *et al.*, 2012). The results of this study revealed that the components present in BF have a low capacity to form a strong film around air bubbles. Therefore, this flour has low potential for applications where these properties are desired, as in bakery products. However, this characteristic does not limit the application of this flour in other products or its use for partial replacement of wheat flour.

Fresh pasta characterization

Chemical characterization

The addition, BF in the fresh pasta formulation did not significantly affect the moisture or protein contents of the fresh pasta. The lack of difference in protein content of the fresh pasta with control formulation was due to the protein content of the BF, which was similar to that of wheat flour (8.57–9.00 g/100 g) (Carreira *et al.*, 2008). The lipid content decreased significantly from 4.36 to 2.29–2.89 g/100 g with the addition of BF to the fresh pasta formulations. This decrease may be related to the low lipid content present in the composition of BF (0.45 g/100 g), which was even lower than that found in wheat flour (1.29 g/100 g) (Carreira *et al.*, 2008).

The ash content in the fresh pasta increased significantly with the increase in the addition of BF. This behavior is due to the high ash content present in BF (5.62 g/100 g), which is higher than that reported for wheat flour (0.75 g/100 g) (Carreira *et al.*, 2008). The ash content is usually associated with the presence of minerals from beet. The main minerals found in beets are iron, calcium, sodium, zinc, manganese, and potassium (Kale *et al.*, 2018). The inclusion of BF in cookies increased the mineral content (Chauhan and Rajput, 2018; Sahni and Shere, 2016). According to Guimarães *et al.* (2018), human health can be improved by the consumption of these minerals; for example, potassium decreases systolic blood pressure, iron deficiency has been associated with fatigue and with an increased risk of cardiovascular/thromboembolic events, and calcium prevents osteoporosis and fractures in adulthood and old age. Furthermore, adequate quantities of sodium ensures the maintenance of normal cellular homeostasis and the regulation of hydro electrolytic balance and blood pressure (Strazzullo and Leclercq, 2014), while zinc has critical effect in homeostasis, in immune function, in oxidative stress, apoptosis, and aging, and significant disorders of great public health interest (Chasapis *et al.*, 2011). On the other hand, manganese participates in the metabolism of amino acids, lipids, and carbohydrates, among other functions (Szentmihályi *et al.*, 2006).

The fiber content, both soluble and insoluble, also increased significantly with the addition of BF to the fresh pasta. This increase is due to the high fiber content present in BF (23.97 g/mg), which was higher than that found in wheat flour (2.40 g/100 g) (Carreira *et al.*, 2008). The addition of BF also increased the fiber content of cookies (Chauhan and Rajput, 2018; Sahni and Shere, 2016). As a result of all these changes in the macronutrients of the fresh pasta, the caloric value of the formulations also decreased with the addition of BF, indicating that the enriched pastas were less caloric. Fibers are important components of the diet that participate in the regulation

of intestinal functions, such as transit of intestinal mass and fecal volume, which in turn prevent constipation, diseases such as diverticulitis, hyperlipidemia, hyperglycemia, and colon cancer (Zhang *et al.*, 2018).

The concentrations of betalains and phenolic compounds increased significantly in fresh pasta formulations with the addition of BF. For betalains, the highest concentrations were observed for formulations 10BF and 15BF (both 0.16 mg/100 g). Betalains are important red water-soluble pigments in the human diet because they act as antioxidants, combating free radicals, and protecting against some diseases related to oxidative stress (Vasconcellos *et al.*, 2016). Although the incorporation of BF caused an increase in phenolic content on fresh pasta, the different levels of BF added did not produce a significant increase of phenolic content after being enriched with 5% BF. The increase in the content of betalains and phenolic compounds is probably due to the high levels of these compounds present in the BF (0.86 and 88.34 mg/100 g, respectively) (Table 1). The phenolic compounds present in BF is higher than that reported for wheat flour (17.7–25.7 mg GAE/100 g) (Vaher *et al.*, 2010). The addition of BF also increased the content of phenolic compounds and betalains in beef sausage (El-Gharably and Ashoush, 2011) and in Julpyun (Ko and Jeong, 2017).

The addition of BF increased the antioxidant capacity of the fresh pasta. Fresh pasta formulations supplemented with BF showed higher antioxidant activity (1.78–4.76%), compared to 0BF (0.52%). Similar results have already been observed in other studies and attributed to the high content of phenolic compounds and betalains present in BF (El-Gharably and Ashoush, 2011; Jeong *et al.*, 2014; Ko and Jeong, 2017).

According to Pasqualone *et al.* (2016), the supplementation of fresh pasta can be realized to improve its nutritional value and its antioxidant activity. The use of ingredients with nutritional properties is a field that has been explored by other researchers (De Santis *et al.*, 2020; Fradinho *et al.*, 2020; Kowalczewski *et al.*, 2019).

The results in the present study indicated that the addition of BF for partial replacement of wheat flour by BF

in the formulation of ready-made pasta can improve the nutritional and functional values of these pasta, reducing the lipid content and increasing the concentration of total minerals, soluble and insoluble fibers, phenolic compounds, betalains, and antioxidant activity.

Technological characterization
Table 4 presents the results of the technological parameters of fresh pasta with partial replacement of wheat flour with BF. Baking quality parameters are widely used empirical determinants to provide important indications about the quality of the pasta during baking. The cooking time of fresh pasta showed no significant difference between the formulations studied, meaning BF did not interfere with the cooking time of the pasta. In the present study, the cooking time was shorter than cooking times previously observed for pasta with pigeon pea flour (Casagrandi *et al.*, 1999), *S. platensis* (Lemes *et al.*, 2012), and fresh multigrain pasta (rice, oat, and soy) (Oliveira Filho *et al.*, 2021).

The statistical analysis of the averages used the Tukey test, whereas the same letters on the columns represent no significant differences at the significance level of 5%.

The substitution of wheat flour for BF did not significantly change the cooking time (approximately 5 min) (P < 0.05), the displaced volume (14.5–15.0%), or the loss of solids (2.57–3.25) in the enriched formulations. There was lower water loss in fresh pasta with BF when compared to fresh pasta with *S. platensis* (Lemes *et al.*, 2012). Except for the 15BF formulation, the volume displacement was lower than presented by Lemes *et al.* (2012) for fresh pasta with *S. platensis* and higher than those reported by Oliveira Filho *et al.* (2021) due to the presence of a matrix composed of rice, oat, and soy that participate more efficiently in the structuring of the fresh pasta.

On the other hand, cooking loss represents the quality of solids lost in water during the cooking process of the pasta. The lower the loss of organic matter during this process, the better the product quality (De Santis *et al.*, 2020), and this value should not exceed 10 g per 100 g of dry pasta (Wu *et al.*, 1987). All formulations developed

Table 4. Technological properties of fresh pasta developed and enriched with beet flour.

Properties	0BF	5BF	10BF	15BF
Cooking time (min)	5.3 ± 0.6[a]	5.0 ± 0.0[a]	5.0 ± 0.0[a]	5.0 ± 0.0[a]
Water retention capacity (%)	156.59 ± 28.71[ab]	187.36 ± 23.09[a]	117.97 ± 15.04[b]	167.71 ± 8.04[ab]
Volume displacement (%)	14.50 ± 0.50[a]	14.50 ± 0.50[a]	14.66 ± 0.58[a]	15.00 ± 0.0[a]
Loss of solids (%)	2.57 ± 0.82[a]	2.63 ± 0.11[a]	3.12 ± 0.07[a]	3.25 ± 0.60[a]
Water absorption (%)	61.30 ± 6.67[a]	52.94 ± 6.77[ab]	52.73 ± 8.27[ab]	32.13 ± 13.81[b]

in this study showed values below 3.3%, which was lower compared to fresh pasta with β-glucan 12.1–14.1 g/100g (De Santis *et al.*, 2020) and similar to that observed in fresh pasta with the addition of brown flour 2.75–3.75 g/100g (Littardi *et al.*, 2020). Water absorption decreased when wheat flour was replaced with BF in fresh pasta. The 15BF formulation showed half of the water absorption compared to the control formulation. This characteristic may be due to the solubilization of the starch during gelatinization. Formulations with a higher BF content showed a reduction in the wheat flour content and consequently in the starch content and gelatinization.

Sensorial profile

Table 5 shows the results of the sensory analysis of fresh pasta with the addition of BF. The formulations differed significantly in the attributes of red color, homogeneous appearance, beet aroma, beet flavor, sweet flavor, and homogeneous texture in the mouth. Formulations with BF addition showed the highest intensity for these attributes, and the highest values were observed for formulations with the highest concentrations of BF (10BF and 15BF). In particular, evaluations of taste, texture, and appearance characteristics of fresh pasta suggested that the addition of BF increases the sensory complexity of the product, as confirmed by the higher value expressed by the judges for formulations with higher concentrations of BF (Table 5).

Similar behavior was reported by El-Gharably and Ashoush (2011) for sausages with BF added. The formulations that contained 1 and 3% of BF demonstrated the highest sensory scores among the samples of beef sausage. According to Oliviero and Fogliano (2016), the incorporation of vegetables can lead to changes in the sensory attributes of fresh pasta. Therefore, for this

strategy to be successful, it is necessary that during processing conditions are optimized so that the final product has the desired nutritional and sensory characteristics.

Conclusions

In general, the results of the present study showed that the addition of BF can be a promising strategy in the development of new formulations of fresh pasta. To our knowledge, the results of the present study indicate for the first time the evaluation of the physicochemical modifications produced in fresh pasta formulations by the addition of BF. The partial replacement of wheat flour with BF in the formulation of ready-made pasta improved the nutritional and functional profile of fresh pasta, reducing the lipid content and increasing the concentration of total minerals, soluble and insoluble fibers, phenolic compounds, betalain content, and antioxidant activity. Regarding the sensory profile, the pastas formulated with the highest concentrations of BF registered the highest scores for the sensory attributes. However, further studies would be needed to assess the changes in terms of texture and bioactive properties of the pasta after cooking, and also to investigate the use of BF in the formulation of gluten-free pasta.

Author Contributions

Josemar Gonçalves de Oliveira Filho, Ailton Cesar Lemes, and Eliane Dalva Godoy Danesi were involved in the original draft preparation. Ailton Cesar Lemes, Ricardo Pereira Cruz Filho, Rafaiane Macedo Guimarães, Kamylla Lina Oliveira, Gabriela Silva Santana, and Eliane Dalva Godoy Danesi were concerned with methodology and investigation. Mariana Buranelo Egea was involved in conceptualization, funding acquisition, supervision, writing, reviewing, and editing

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Table 5. Sensorial profile of fresh pasta developed and enriched with beet flour.[1]

Attributes	0BF	5BF	10BF	15BF
Red color	10[a]	20[ac]	31[bc]	39[b]
Homogeneous appearance	13[a]	22[acd]	29[bcd]	33[bd]
Egg aroma	20[a]	23[a]	28[a]	26[a]
Beet aroma	11[a]	23[b]	29[b]	37[b]
Beet flavor	10[a]	21[acd]	31[bc]	38[bd]
Sweetness flavor	13[a]	22[ac]	28[bc]	37[bd]
Homogeneous texture in the mouth	17[a]	21[ac]	29[bc]	33[bd]

Sum of RDA values for 12 judges. [1]Different letters on the same line indicate a significant difference (P < 0.05), compared with Newell and MacFarlane's (1987) table. Critical value: 12 (4 samples and 12 judges).

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