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Enrichment of fresh pasta by the percentage replacement of wheat flour by flour made from Dipteryx alata Vog. (baru)

Enriquecimento de massas frescas pela substituição percentual da farinha de trigo por farinhas feitas a partir de *Dipteryx alata Vog.* (baru)

Abstract

Introduction: Food has a significant impact on health and quality of life. Taking full advantage of food reduces waste and improves the nutritional quality of the menu. A typical fruit of the Cerrado, baru (Dipteryx alata Vog.) has nutritional potential and economic appeal. Its processing generates by-products that can be used to enrich or add nutritional value to several products. Objective: The present study evaluates the use of broken almond flour and baru cake flour (by-products) as ingredients in pasta, replacing part of the wheat flour. Method: Fresh pasta containing proportions of 10% and 20% of these flours were prepared. Physicochemical analyzes were performed and technological characteristics of these masses were established. Results: Pasta with baru flour had a higher content of lipids (increase between 10.08% and 103.36%) and proteins (increase between 20.65% and 34.60%), while carbohydrates were reduced (reduction between 3.14% and 5.46%). Color analysis of the masses showed an influence on the characteristics of luminosity, hue and saturation, indicating a darker coloration (where the L* coordinate had a reduction of 72 to the mean of 45, the a* coordinate, an increase of 3.63 to values between 4.87 and 6.35; and the b* coordinate, a reduction of 19.48, reaching values of up to 10.93). The results indicate that the pasta produced showed cooking time, water absorption, increased volume and loss of solids in the cooking water within the expected range, indicating a good technological characteristic. Conclusion: Partially replacing wheat flour with almond flour and baru cake may be a promising strategy for producing pasta that is more nutritious. The partial replacement of wheat flour with almond flour and baru cake may be a promising strategy for producing pasta with a lower carbohydrate content. The use of these by-products represents a viable alternative to reduce waste and add value to the baru production chain.

Keywords: Full use. Fruit of the Cerrado. By-products Broken almond. Baru cake.

Resumo

Introdução: A alimentação impacta significativamente na saúde e na qualidade de vida. Aproveitar integralmente os alimentos reduz o desperdício e melhora a qualidade nutricional do cardápio. Fruto típico do Cerrado, o baru (Dipteryx alata Vog.) apresenta potencial nutritivo e apelo econômico. Seu processamento gera subprodutos que podem ser utilizados para enriquecer ou agregar valor nutricional a diversos produtos. **Objetivo:** O presente estudo avalia o uso da farinha de amêndoa quebrada e da farinha da torta do baru (subprodutos) como ingredientes em massas alimentícias, substituindo parte da farinha de trigo. **Método:** Foram elaboradas massas frescas contendo proporções de 10 e 20% destas farinhas. Análises físico-químicas e das características tecnológicas dessas massas foram realizadas. **Resultados:** As massas com as farinhas de baru apresentaram maior teor de lipídios (aumento entre 10,08% e 103,36%) e proteínas (aumento entre 20,65% e 34,60%), enquanto os carboidratos foram reduzidos (redução entre 3,14% e 5,46%). Análises de cor das massas mostraram influência nas características de luminosidade, tonalidade e saturação, indicando uma coloração mais escura (onde a coordenada L* teve redução de 72 para a média de 45, a coordenada a*, um aumento de 3,63 para valores entre 4,87 e 6,35; e a coordenada b*, uma redução de 19,48, atingindo valores de até 10,93). Os resultados indicam que as massas produzidas apresentaram tempo de cozimento, absorção de água, aumento de volume e perda de sólidos na água de cozimento dentro do esperado, indicando uma boa característica tecnológica. **Conclusão:** A substituição parcial da farinha de trigo por farinhas de amêndoa e torta de baru pode ser uma estratégia promissora para a produção de massas alimentícias mais nutritivas e com menor teor de carboidratos. A utilização desses subprodutos representa uma alternativa viável para reduzir o desperdício e agregar valor à cadeia produtiva do baru.

Palavras-chave: Aproveitamento integral. Fruto do cerrado. Subprodutos. Amêndoa quebrada. Torta do baru.

INTRODUCTION

According to data from the Food and Agriculture Organization of the United Nations (FAO), approximately 1.3 billion tons of food are discarded annually worldwide, and Brazil is among the 10 countries with the highest rate of food waste.[1] When analyzing the food production chain, we observe that waste occurs at all stages, from production to final consumption.[2] The increase in food waste and the volume of waste generated from these losses have been generating increasing global mobilization, due to the socioeconomic importance and negative environmental impact of this crop.[3]

We observe an increase in society's awareness of the impact that food has on health promotion, quality of life and sustainability.[4] Several studies and campaigns for the sustainable consumption of food, combating waste and aiming at reducing losses have been launched to try to minimize this impact.[1,2] Among the existing possibilities, we have the full use of food, which is the use of unconventional parts, such as bark, seeds, stalks, leaves, etc. From this perspective, the parts that would traditionally be discarded can be incorporated into the diet, as they may even contain more nutrients than the commonly consumed portions.[5]

The full utilization of food, in addition to reducing food expenses[2] and improving the nutritional quality of meals, also minimizes waste and enables the creation of new recipes, such as juices, sweets, jams, flours, among others.The composition of waste from food processing is extremely varied and depends on the nature of the raw material.[6]

Studies show that the fruit species of the Cerrado are rich in biodiversity. Its fruits are of great interest to the food industry, as, in addition to its sensory characteristics, it has nutritional properties beneficial to health.[7] Among the various native fruit species of the Cerrado, the barueiro (Dipteryx alata Vog.) is considered very promising for cultivation, as it has multiple uses, including medical, food, industrial, timber, landscape and environmental.[7,8]

Barley fruits are classified as drupes. They are oval in shape, dark beige to reddish brown in color, with an average mass of 26 g, a length of 5 cm and a width of 4 cm. They consist of the epicarp (peel), a thin and rough layer; the mesocarp (pulp), a fleshy, fibrous and sweet layer (corresponding to 30% of the fruit's weight); and the endocarp, a hard and woody layer that coats a single seed called an almond or walnut (about 5% of the fruit's weight).[9,10]

Baru is rich in proteins of high biological value, as it contains unsaturated fatty acids, fibers, minerals and also antioxidant properties.[11] It therefore has great nutritional potential and strong economic appeal, which makes it an accessible raw material from which new food products can beformulated.[7]

The baru nut has an oval to elliptical shape and is coated with a thick brown skin.[10] It is the most valued portion of the fruit, being highly appreciated in culinary preparations and has been widely studied.[9] Different steps are adopted during baru processing, impacting the generation of various by-products, depending on the level of transformation and the technology used. The main process is the extraction of the almond from the inside of the fruit, from where the almond is obtained and a large amount of peel and pulp. The almond corresponds to only 5% of the weight of the fruit [12.]

To remove the almond from the baru, we need to break the core (endocarp), which is very hard.[13] This is a process not yet standardized and most often performed manually. Many industries still perform separation using knives or guillotines; but other options have been identified, including the use of hammers, sickles, presses, and other adapted methods, but which can cause damage to the almond. In these processes, there is the presentation of a solid by-product, consisting of epicarp, endocarp, mesocarp, in addition to broken almonds.[12,14]

Almonds are also a source of high quality oil, characterized by a high content of linoleic acid, depending on the composition of their fatty acids.[13] The extraction of baru oil can be carried out by cold pressing, by conventional processes with organic solvents or by means of compressed solvent technology, among other methods. This process results in two fractions: baru oil and partially defatted almond cake, which can be used for the extraction of protein material.[12]

Studies have shown the technological use of baru nuts and their by-products in the preparation of various food products. From this fruit, advantage can be taken of the pulp (consumed *in natura* or in the form of sweets, liqueurs, ice cream, etc.), and the almond (which can be roasted for the production of flour, or consumed *in natura*). It is also possible to obtain oils from the processing of its almonds (used in human food, in the pharmaceutical or cosmetic industry).[7] At the end of the production process, by-products are generated that can still be used to enrich or add nutritional value in various products, such as breads, pastas, cereal bars and others. Among the by-products are the broken almond, baru almond actor (which is a partially defatted mass from the extraction of almond oil) as well as the pulp (composed of epicarp and mesocarp).[12]

Pasta is part of the Brazilian diet and, although fresh pasta is not considered a nutritionally balanced food due to its low fiber content, bioactive compounds and protein biological value, nevertheless they have a high rate of acceptability. In addition, it is a fast and easy-to-prepare, versatile, low-cost food, which makes them a good vehicle for nutritional enrichment.[15]

As sources of information for this work, several studies were observed for the preparation of pasta with the addition of flours of the most varied origins, such as passion fruit seed flour,[16] beet flour,[17] the use of brewer bagasse,[18] among others.

Based on the above, considering the full use of baru, this study aims to evaluate the influence of replacing wheat flour with flour produced from by-products of the almond Dipteryx alata *Vog*. (baru) on the physicochemical and technological characteristics of fresh pasta (pasta). Replacement flours were prepared from the broken baru almonds and cake (by-product of oil extraction from baru almond).

METHODS

Materials

The baru and broken almond cake samples were obtained in partnership with the Florir de Sal Natural Products Industry, located in Goiânia/GO. The cake was obtained as a by-product of the baru oil extraction process, carried out by cold pressing. The raw materials were stored in a freezer until use (5-day period). The other ingredients used for the production of pasta were obtained from the local commercial establishments in Goiânia: wheat flour (Cristal Alimentos, Goiânia/GO), eggs (Ovos Jusidith, Leopoldo de Bulhões/GO) and salt (Sal Cisne®, São Paulo/SP).

Flour preparation (FA and FT)

Fresh almonds are not recommended for consumption, as they may contain substances with antinutritional properties [9]. Lemos et al.,[19] when evaluating the effect of roasting on these compounds, observed the effectiveness of heat against their inhibition, making almond consumption safe.

Therefore, for the preparation of the flours, the samples of baru almonds and cake were roasted in an oven (Tecnal brand, model TE-395), at 120°C for 20 minutes.[4] Then, they were crushed in a blender (Mondial brand, model L66 – 10 speeds).

Production of fresh pasta

The processing of fresh dough was as described by Lemes et al.[19] Briefly, the standard formulation contained 150g of wheat flour, one egg, and 1g of salt and 40g of water. FA and FT replaced wheat flour in the percentages of 10% (15g) and 20% 30g). Only the quantities of wheat flour were changed during production, from which 15 and 30 grams, respectively, were taken from the pasta, and the same amount of FA and FT were added. The pasta formulations, in grams, are described in Table 1.

Table 1. Ingredients and proportions used in the formulation of fresh reference pasta and pasta enriched with FA 10 and 20% and FT 10 and 20%. Goiânia, Goiás, 2023.

Ingredients (g)	REF	FA 10%	FA 20%	FT 10%	FT 20%
Wheat flour	150	135	120	135	120
Egg (1 entire egg)	43	43	43	41	42
Salt	1	1	1	1	1
Water	40	40	40	40	40
FA	–	15	30	–	–
FT	–	–	–	15	30

All ingredients were weighed and mixed manually. The resulting masses were modeled and allowed to stand for 30 minutes. Then, the lamination and cutting was carried out with the aid of a Marcato dough cylinder, Atlas 150 Classic model, in the shape of a noodle. Finally, the masses were stored under refrigeration (for 24 hours) until the analysis was performed.

Only one batch of dough was produced, from which the triplicates were taken to make the proximate composition.

Determination of proximal composition and physicochemical analyses

The proximal composition of the flours and fresh doughs (reference dough and fresh doughs enriched with FA 10%, FA 20%, FT 10% and FT 20%) were determined for moisture, ash, proteins and lipids according to the analytical standards of the Adolfo Lutz Institute,[20] and following the methods recommended by the Association of Official Analytical Chemists.[21] The moisture content was determined by oven desiccation at 105°C ± 2°C and ash by incineration in a muffle furnace at 550°C, both until reaching constant weight. Protein content was obtained relative to total nitrogen by the micro-Kjeldahl method and converted to crude protein by the factor 6.25. Lipid content was determined by the Soxhlet method, using petroleum ether as the solvent. Analyses for the proximal composition were performed in triplicate, and the results expressed in g/100g. The carbohydrate content was estimated by the difference method, subtracting 100 from the values obtained from moisture, ash, proteins and lipids. The total energy value was calculated using the coefficients of Atwater and Woods (1896), in which digestible carbohydrates have 4.0 kcal/g, lipids 9.0 kcal/g and protein 4.0 kcal/g.

Color Determination

For color analysis, the CieLab parameters (L*, a* and b*) were determined using a Color Quest II colorimeter (Hunter-Lab, Reston, Virginia, USA) according to the method described by Paucar-Menacho et al. [22] The L* coordinate defines luminosity (L*=0 black and L*=100 white), and the a * and b* coordinates define chromaticity (+ a * red and -a* green, +b* yellow and -b* blue). The colorimeter was standardized using white and black calibration plate.

Determination of water activity (Aw)

The determination of the water activity of the flour and fresh dough samples was carried out in a digital AquaLab device, model CX-2, manufactured by DECAGON, coupled to a thermostatic bath with controlled temperature between 24°C and 27°C.

Cooking time, water absorption, volume increase and solids loss in cooking water (technological quality)

The technological quality analyzes were made according to the 66-50 methodology of the American Association of Cereal Chemists,[23] with adaptations. The cooking time was determined from the cooking of 5g of product placed in 250mL of boiling distilled water. During baking, the dough was removed every 1 minute to check for the disappearance of the central white core by squeezing it between two glass plates. For the water absorption analysis, a 5g sample was subjected to cooking, and its mass was measured later, considering the ideal cooking time obtained by the previous analysis. The volume increase analysis was performed using a 100mL beaker containing 60mL of water, in which the volume increase was determined by the ratio between the displaced volume of water per 5g of product before and after cooking. The determination of the loss of soluble solids was performed from the measurement, in a beaker, of the water drained after cooking the pasta, from which an aliquot of 10mL was removed and placed in Petri dishes, which was taken to the oven at 105ºC, until reaching constant weight. All analyses were done in duplicate.

Statistics

Analysis of variance (ANOVA) test was employed to evaluate the difference between formulations. Tukey's test at the 5% probability level was used to compare means. Data were analyzed using the RStudio software, version 4.2.2 (2022-10-31 ucrt).

RESULTS

Characterization of baru almond (FA) and baru cake (FT) flours

Table 2 shows the values found in the proximate composition and water activity of baru almond flour (FA) and cake (FT). Values of 3.08% and 3.29% were found for moisture; 41.99% and 22.52% for lipids; 2.92% and 2.30% for ash; 25.13% and 26.14% for proteins; and 29.95% and 49.07% for carbohydrates, respectively, for FA and FT. In the analysis of almond flour, the present study found values consistent with those found by Coutinho,[4] who obtained approximate values for baru almond of 2.94% for moisture, 3.26% for ash, 24.39% for proteins and 47.50% for lipids. Also consistent with those found by Oliveira-Alves et al.,[11] who obtained 3.20% moisture, 3.24% ash, 27.06% protein and 45.80% lipids. As for baru cake flour, Moreira et al.,[24] obtained approximate values of 5.41% moisture, 3.54% ash, 46.12% lipids and 17.87% proteins, which differ slightly from the values of Borges et al.,[25] who found 5.10% for moisture, 4.12% for ash, 25.12% for lipids and 34.42 for proteins. It is noteworthy that seeds, grains and almonds may have a variation in their properties based on location, type of cultivation and the climatic conditions to which the trees are exposed, which justifies some divergences found in the literature.[26] Moreira et al.[24] justify the high lipid content in the mechanical pressing system, which may not have been able to remove all the oil content present in the almond.

Table 2. Centesimal composition of baru almond flour (FA) and cake (FT). Goiânia, Goiás, 2023.

Components (g/100g)	FA[1]	FT[1]
Humidity	3,08±0,04[b]	3.29±0.03[a]
Total Lipids [2]	41.99±0.62[a]	22.52±0.47[b]
Ash [2]	2.92±0.07[a]	2.30±0.03[b]
Proteins [2]	25.13±0.13[b]	26.14±0.39[a]
Carbohydrates [2, 3]	29.95[b]	49.07[a]
Total Energy Value [2] (kcal/100g)	598.23[a]	503.40[b]
Water Activity [4]	0.635[a]	0.571[b]

[1] Values constitute mean ± standard deviation (triplicate analysis).
[2] Values are represented on a dry basis.
[3] Calculated by difference, subtracting from 100 the values obtained for moisture, total lipids, ash and proteins
[4] Dimensionless value.
.* Equal letters in the lines indicate no significant difference ($p<0.05$) by the Tukey test between the formulations.

According to RDC No. 711, of July 1, 2022, of ANVISA, the water content of flour materials should not exceed the value of 15g /100g.[27] Water activity values (Aw) close to 0.60 delay undesirable actions of microorganisms and enzymes, which characterizes a chemically stable material and is easy to incorporate into food formulations.[28] The humidity of the flours produced are in accordance with the recommendations of current legislation, and the values for water activity found in FA and FT demonstrate the potential of these flours.

By ANOVA statistical analysis, the analyzed properties of the FA and FT samples differed significantly from each other. The FA sample has higher levels of lipids (86.46%) and ash (26.96%), while the FT sample has higher levels of moisture (6.82%), proteins (4.02%) and carbohydrates (63.84%). The difference in the composition directly impacts the total energy value, which makes FT less caloric than FA (18.84%), mainly due to the lower lipid content. The physical extraction of baru oil from the almond passes part of the nutritional quality and antioxidant properties to the oil, and a part is retained by the cake, which justifies the difference between the compositions of FA and FT.[29]

Characterization of fresh pasta produced

The nutritional composition of pasta is related to the ingredients used in the preparation and the type of processing adopted. Table 3 shows the proximate composition of the fresh pasta produced in this study.

Table 3. Proximal composition, energy value, color properties, water activity (WA) and technological parameters (cooking time, water absorption, increase in volume and losses of soluble solids) of the different fresh pasta formulations. Goiânia, Goiás, 2023.

Components (g/100g)	REF¹	FA 10%¹	FA 20%¹	FT 10%¹	FT 20%¹
Humidity	35.26±0.28[a]	33.25±0.28[bc]	32.11±0.22[c]	34.35±0.8[b]	34.05±0.05[b]
Total Lipids²	1.19±0.24[b]	1.85±0.34[ab]	2.42±0.16[a]	1.31±0.30[b]	1.56±0.72[ab]
Ash²	3.28±0.01[a]	3.37±0.06[a]	2.78±0.03[b]	2.16±0.09[d]	2.42±0.03[c]
Proteins²	14.19±0.18[d]	17.12±0.43[bc]	17.42±0.56[bc]	17.73±0.24[ab]	19.10±0.29[a]
Carbohydrates [2, 3]	81.35[a]	77.66[c]	77.38[d]	78.80[b]	76.91[e]
Total energy value (kcal/100 g)	392.87[d]	395.81[c]	400.98[a]	397.91[bc]	398.08[ab]
Color (L*)	72.30±2.50[a]	54.13±2.45[b]	48.21±1.83[c]	45.62±3.32[c]	46.50±2.44[c]
Color (a*)	3.63±0.25[d]	4.87±0.31[c]	5.25±0.42[bc]	5.80±0.40[ab]	6.35±0.48[a]
Color (b*)	19.48±0.83[a]	13.60±0.79[b]	12.21±1.30[c]	10.93±0.80[c]	11.62±0.68[c]
Aw [4]	0.959[bc]	0.952[c]	0.962[ab]	0.969[a]	0.966[ab]
Cooking time (min)	7.15[c]	7.35[b]	7.10[c]	8.20[a]	8.10[a]
Water absorption	194.81±0.12[b]	205.78±0.11[a]	181.97±0.10[e]	183.35±0.26[d]	188.25±0.03[c]
Increase of volume	108.59±0.01[a]	108.59±0.01[a]	107.03±0.01[b]	107.90±0.04[ab]	108.67±0.01[a]
Loss of soluble solids	5.87±0.01[a]	6.56±0.01[a]	6.49±0.01[a]	6.28±0.01[a]	6.21±0.01[a]

1 Values constitute mean ± standard deviation (triplicate analysis).
2 Values are represented on a dry basis.
3 Calculated by difference, subtracting from 100 the values obtained for moisture, total lipids, ash and proteins
4 Dimensionless value.
* Equal letters in the lines indicate no significant difference ($p<0.05$) by the Tukey test between the formulations

The centesimal composition of the dough prepared with wheat flour (REF) showed approximately 35.26% moisture, 1.19% total lipids, 3.28% ash, 14.19% protein and 81.35% carbohydrates, with a total of 392.87 kcal/100g of dough. Compared to this, we obtained significant differences in the values of ash, protein and carbohydrates for all other developed masses. For moisture and ash values, only FA 10% showed no significant difference; and for lipid values, only FA 20% diverged significantly.

Resolution RDC No. 93, of October 31, 2000, of ANVISA, defines the classification of pasta, according to the moisture content, as dry mass (maximum humidity 13%), wet or fresh mass (maximum humidity 35%) and instant or pre-cooked mass dehydrated by frying process or hot air (maximum humidity between 10% and 14.5%, according to the dehydration method).[30] With its repeal and given that RDC No. 711, of July 1, 2022 (ANVISA), in force, determines that pasta can be presented as dry, fresh, pre-cooked, instant or ready for consumption, it is understood that the classification regarding humidity remains. Therefore, by the humidity presented in the developed pasta, they are classified as fresh mixed pasta. Although the reference mass has slightly exceeded the limit of 35% humidity, all others meet the parameter.[27] One point of attention that high moisture contents bring is that they can influence the texture of the masses, and can also determine their useful life, since high humidity favors the development of microorganisms, reducing their validity.[31]

Pietro,[31] in his study, elaborated fresh mixed pasta, partially added with baru pulp (10, 15 and 20%). In their analyses, the results of ash, protein, lipid, carbohydrate and energy content did not differ statistically between any of the formulations. However, variations were observed in moisture contents, with a significant difference between the control sample (30.89% moisture) and the sample containing 20% baru pulp (32.23% moisture). Due to the different compositions between the almond and cake flours of baru pulp flour, and the significant differences found, the present study shows that the replacement of wheat flour by FA and FT adds nutritional value to the pasta, in addition to having a positive environmental and economic impact.

This impact is due to the fact that the use of baru by-products as ingredients in food products adds value to this native Brazilian fruit, with great impact on the economy, industry, technology and sustainable development of the region,[7] in addition to promoting the reduction of waste.

With regard to lipid contents, as expected, the mass with the highest content in this regard is that enriched with FA 20% (2.42% total lipids), in view of the oleaginous nature of the baru almond and because it is present in higher concentration in this sample. Despite this, the values of FA 20% do not differ significantly from the values found for FA 10% and FT 20%, which are 1.85% and 1.56%, respectively.

The masses that obtained the highest protein contents were those enriched with FT 10% (17.73%) and FT 20% (19.10%), which did not differ significantly from each other. And, despite containing less protein than FT 10% and FT 20%, according to Brazilian legislation, the masses produced can be labeled as a source of protein, as all presented more than 10g of protein in 100g of mass; and also, as low-fat foods, as they have less than 3g of fat in 100g of mass.[32]

The carbohydrate content of pasta was reduced with the incorporation of FA and FT, with the percentage of carbohydrate in the reference mass being 81.35%, a value reduced to 76.91% in the mass enriched with FT 20%. This reduction was also observed by Antunes et al.,[33] whose object of study was pasta enriched with baru pulp flour, in which the reference pasta had 66.43% carbohydrates, against 61.69% in the pasta enriched with 20% baru pulp flour.

Finally, there is an increase in the total energy value of the pasta produced, with a percentage of substitution for wheat flour, which can be attributed to the significant increase in protein and lipid contents, considering that the carbohydrate content of pasta was reduced with the incorporation of FA and FT.

The replacement of wheat flour with flour from baru by-products contributes to the nutritional composition of pasta. It is important to consider that the reduction of the glycemic index of the products can contribute to functional improvement, and this is due to the decrease in the amount of carbohydrates and the increase in the content of lipids and proteins.

Colouring of fresh pasta

Regarding the color of raw pasta, the parameters L*, a* and b* were evaluated, according to the color system standardized by CieLab. The lightness-related parameter (L*) indicates the lightness or darkness of the sample, where zero indicates totally dark (black) and 100, totally light (white). The a* chromatic coordinate defines whether the sample tends to redness (values between 0 and 100) or greenish (values from -80 to 0).

In addition, the chromatic coordinate b* defines the color in relation to yellow (0 to 70) or blue (-100 to 0). The values obtained by the fresh pasta formulations are shown in Table 3.

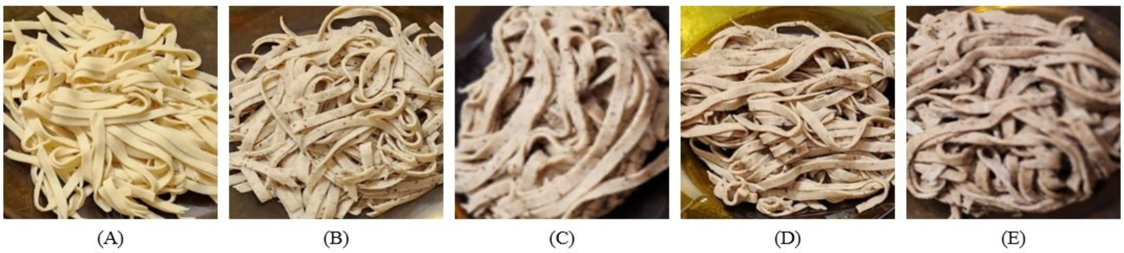
The luminosity value (L*) of the reference mass was 72.30, and the brightness decreases as FA and FT were added to the product, reaching the value of 45.62 for 10% FT mass, resulting in a darker shade to the mass. In the work of enriching pasta, with the replacement of wheat flour by other types of flour or nutritional components, the lightness coordinate tends to go from a lighter point to a darker, or one of less light. Ferreira et al.,[34] found an average of 78.77 L* for the control mass, and the added mass of 20% of ora-pro-nobis powder presented an average of 49.58, due to the dark green hue that the mass acquired. Pietro,[31] found means of 63.38 for the L* coordinate in the control sample, and 44.07 in the formulation with 20% baru pulp flour, a value close to that found in the present study. Nascimento[28] found means of 70.24 L* for the control mass and 45.36 for the concentration of 20% moringa powder (*Moringa oleifera Lam*.).

For the a* coordinate, the values increased with the replacement of wheat flour (3.63 in the reference dough, against 6.35 in the FT 20% dough). Ferreira et al.[34] found negative means in samples with higher concentrations of powder from ora-pro-nobis leaves in the masses (3.73 to -0.22). This is because the masses elaborated by Ferreira et al.[34] presented the green color, a characteristic color of the powder of ora-pro-nobis, which contributed to this result. In Pietro's study[31] the values were 3.03 for the control dough, against 9.00 in the dough with a 20% formulation of baru pulp flour, varying much more than in the present study. And in the study by Silva et al.,[35] the parameters ranged from 1.68 in the control dough to 5.42 in the dough with 20% dry sprout flour.

The values of the b* coordinate are positive, reducing from 19.48 in the reference mass to 10.93 in the FT 10% mass, and its value does not differ significantly from the masses FA 20% (12.21) and FT 20% (11.62). In the study by Silva et al.,[35] the parameters ranged from 14.39 in the control mass to 6.83 in the mass with 30% dry sprout flour, and the masses with 10 and 20% dry sprout flour being the values that most closely match the values found in this study (11.95 and 10.27, respectively). The values found by Pietro[31] varied from 26.53 in the reference mass to 19.37 in the formulation with 20% baru pulp.

As expected, because FA and FT are darker in color than wheat flour, the formulations elaborated present significant differences in color in relation to the reference mass, for the L*, a* and b* coordinates. Figure 1 shows the masses produced.

Figure 1. Color of pasta made with different concentrations of baru by-product flours. Reference mass (A), FA 10% (B), FA 20% (C), FT 10% (D) and FT 20% (E)



Source: Authors own (2023).

The color of pasta is considered an important parameter of quality and acceptance for the consumer. Generally, the acceptable standard is that pastas have a bright yellow color.[36] Often, the color generates a visual impact that can overlap with the impacts caused by appearance and odor, which can affect the intensity of taste perception. The results obtained for the color parameters indicate that the pasta added with baru pulp were influenced by the color from the almond, which has a color closer to brown, as shown in Figure 1. However, the values are close to those found in other studies that had good acceptability in the sensory tests concerning the color question, enabling the present study.[28,31,34,35]

Water activity (Aw)

The main food safety criterion in dry pasta, according to Ferreira et al.,[34] stems from the verification of water content. The water activity of the masses should be around 0.650, corresponding to the safe moisture content, to prevent moulds from surviving.[28] In this study, the samples presented Aw values higher than the recommended value, probably because they are fresh, not dry, pasta. The mass FT 10% was the one with the highest water activity (0.969), with no significant difference between it and the masses of FA 20% and FT 20%, which presented Aw equal to 0.962 and 0.966, respectively. And the mass with the lowest water activity was FA 10%, with a value equal to 0.952, which does not differ significantly from the reference mass (see Table 3). The values are close to those found by Silva et al.,[35] in which the water activity of the prepared pasta ranged from 0.950 to 0.970.

Fresh pasta is usually marketed with practically the same moisture and water activity as when molded, and its main mechanism of deterioration is the growth of fungi and yeasts. Use of modified atmosphere packaging allows a significant increase in shelf life and better product presentation. Another alternative is to pasteurize the product before packaging, as well as reducing the microbial load, it helps to improve the consistency of the dough and make it less susceptible to contamination. The pasta pasteurization process is usually carried out in continuous tunnels, where the product comes into direct contact with saturated steam and is then slightly dried and packaged.[37]

Technological features

The analyzes involved in the cooking tests influence the quality of the pasta, in which a low increase in mass indicates low water absorption capacity, resulting in harder pasta with lower sensory quality. In addition, considerable solids losses are undesirable characteristics, which represent high starch solubility, resulting in turbidity in the cooking water and low tolerance to cooking.[15] These cooking tests determine the technological quality of the pasta. The cooking characteristics of the pasta, that is, the ideal cooking time, water absorption rate, the volume expansion percentage and the loss of solids by cooking are shown in Table 3.

The average obtained for the cooking time was 7.58 min, giving the masses speed in the preparation, meeting the demand of current consumers who seek practicality in the preparation of their meals. This average is close to the cooking time found by Pietro[31] and Antunes et al.,[33] who found cooking times ranging between 7 and 8 minutes.

The ideal cooking time is that required to cook the dough until the central white core of the dough has completely disappeared. The replacement of wheat flour by FA and FT resulted in variations in cooking time. The masses FT 10% and FT 20% presented longer times than the reference mass, with an average increase of 14%. On the other hand, the 10% FA mass had an increase of only 2% in time, and the 20% FA mass had no significant difference. Surasani et al.[36] found a linear relationship between the protein content and the cooking time of the pasta, as they report that the protein makes it difficult to gelatinize the starch, forming an inclusion complex with the starch, which can increase the cooking time of protein-rich pasta. Therefore, the differences found in the cooking time of the pasta can be attributed to the different protein contents. It should be noted that pasta with higher protein content, when subjected to boiling, becomes firmer and internally resistant compared to pasta with low protein content.[36]

Fradinho et al.[15] observed changes in the technological characteristics of the masses, due to the incorporation of microalgae biomass. These are significant changes in water absorption, increased volume and loss of solids, a result similar to those observed in fresh mass samples incorporated from FA and FT. However, while in the studies by Fradinho etal.[15] the pastas prepared with Arthrospiraplatensis *(*spirulina) presented greater swelling power than the control, the present study presents an increase higher than the reference mass, only in the FA 10% pasta. This may be due to the ability of the microalgae to absorb water and retain it in the starch-protein network, which does not occur in baru almonds.

Studies carried out by Antunes et al.[33] corroborate the results of the present study, as the partial replacement of wheat flour with baru pulp flour resulted in a decrease in the increase in pasta (increase in the control pasta of 196.80%, while the increase in formulations with 10 and 20% pulp flour was 172.77 and 166.20, respectively). Similar results were found by Pietro,[31] in which the pasta with 100% wheat flour showed an increase in mass equivalent to 213.53% and pasta with 10 and 20% pulp flour had an increase of 172.67% and 155.92%, respectively.

Regarding the volume increase, only the FA 20% value differs significantly from the others, showing a slightly smaller increase (107.90%), while the highest value was observed in the FT 20% pasta with 108.67% increase (value that does not differ from the others). This result differs, however, from that found by Surasani et al.,[36] whose volume expansion of the cooked dough increased significantly with the increase in the content of pangas protein isolates (PPI). Moreover, in the studies by Oliveira Filho et al.[17] the incorporation of beet flour in pasta did not significantly change the cooking time, the displaced volume, or the loss of solids.

The loss of solids by cooking represents the amount of solids lost in the water during the cooking of the dough. The lower the loss of organic matter in this process, the better the product quality.[17] The loss of soluble solids in high quality pasta should not exceed the average of 7 to 8% of its dry mass.[28] Thus, the masses of the present study showed low losses of solids in water, close to 6%, indicating satisfactory results.

CONCLUSION

The use of baru almond and its by-products in food products is an alternative with great potential to be explored. In addition to being alternatives for fortification, innovation and sustainability in food technology, baru is a fruit with a significant nutritional and functional composition. The use of its by-products in formulations is a strategy to reduce waste and add value to new products. The elaborated flours (FA and FT) presented physicochemical characteristics that favored their use in food formulations and contribute to the development of a new product.

The present study allows us to affirm that the pasta incorporated with FA and FT are foods with high nutritional and energy value. The developed pasta presented good technical quality and the incorporation of FA and FT values the application of this Cerrado fruit – baru – in the elaboration of new products, giving them more visibility. The partial replacement of wheat flour by FA and FT improves the chemical composition of the pasta produced. The contents of proteins, lipids and carbohydrates promote a satisfactory nutritional content, which allows them to be classified as low-fat foods and as a source of proteins, and as such is a promising strategy in the development of new formulations of fresh pasta.

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Contributors

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