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Production of gluten-free pasta from black rice by-products: physicochemical, nutritional and sensory attributes

Produção de macarrão sem glúten a partir de subprodutos de arroz preto: atributos físico-químicos, nutricionais e sensoriais

Elaboración de pasta sin gluten a partir de subproductos de arroz integral: atributos físico-químicos, nutricionales y sensoriales

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Pui Vem Chan
ORCID: https://orcid.org/0000-0002-0736-9762
Federal University of São Paulo, Brazil
E-mail: puivchan@gmail.com
Silvia Leticia Rivero Meza
ORCID: https://orcid.org/0000-0002-8299-4701
Federal University of Pelotas, Brazil
E-mail: silvialrmeza@gmail.com
Daniela Leandro Manfre
ORCID: https://orcid.org/0000-0002-0736-9762
Federal University of São Paulo, Brazil
E-mail: daniela.manfre@unifesp.br
Anna Cecília Venturini
ORCID: https://orcid.org/0000-0001-5228-463X
Federal University of São Paulo, Brazil
E-mail: anna.venturini@unifesp.br
Cristiana Maria Pedroso Yoshida
ORCID: https://orcid.org/0000-0003-3068-8187
Federal University of São Paulo, Brazil
E-mail: cristiana.yoshida@unifesp.br
Marcio Schmiele
ORCID: https://orcid.org/0000-0001-8830-1710
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: marcio.sc@ict.ufvjm.edu.br
Patricia Sinnecker
ORCID: https://orcid.org/0000-0002-0736-9762
Federal University of São Paulo, Brazil
E-mail: psinnecker@unifesp.br

Abstract
The manufacture and characterization of gluten-free pasta based on black rice flour by-products from the industrial processing of black rice grains were addressed in this study. The black rice pasta (BRP) was extruded in a penne format developed with black rice flour: white rice flour 1:2 w/w, and the addition of food additives to improve the texture and viscoelasticity proprieties of pasta: tapioca starch, xanthan gum, egg, and water. The cooking quality, texture parameters, CIEL*a*b* color, and total monomeric anthocyanin (TAM) content were evaluated. The optimum cooking time was adjusted to 7 minutes, BRP presented 31.9% of moisture, water absorption of 68.0%, and cooking loss of 4.8%. Texture properties of BRP were positively affected by the presence of additives and presented firmness and adhesiveness values of 2.54 N and 0.01 N, respectively. Cooked BRP presented 10.4 mg of cyanidin-3-glycoside / 100 g (dry basis), carrying a reduction of only 16% of the TAM content related to the dough before cooking. Sensory analysis performed with 100 untrained testers showed high acceptance indexes (between 67% and 89%), with flavor and texture the most well-evaluated attributes contributing to an expressive purchase intention (86%) if the product was available for sale. It was possible to reuse a residue from black rice-processing and develop an innovative, high-quality gluten-free pasta, with a peculiar chestnut flavor, a natural purple color, with nutritional properties, antioxidants and being gluten-free, it is a product with potential to benefit and increases the diversity of food for celiac patients.
Keywords: Black rice byproduct; Anthocyanins; Pasta; Technological quality; Consumer acceptability.

Resumo
A fabricação e caracterização de macarrão sem glúten à base de subproduto do beneficiamento arroz preto foram abordadas neste estudo. O macarrão de arroz preto (MAP) foi extrusado em formato penne desenvolvido com farinha

de arroz preto: farinha de arroz branco 1:2 p/p, e aditivos alimentares para melhorar a textura e propriedades de viscoelasticidade: amido de tapioca, goma xantana, ovo e água. A qualidade de cozimento, parâmetros de textura, cor CIEL*a*b* e teor de antocianinas monoméricas totais (AMT) foram avaliados. O tempo ótimo de cozimento foi de 7 minutos, o MAP apresentou 31,9% de umidade, absorção de água de 68,0% e perda de cozimento de 4,8%. As propriedades de textura foram afetadas positivamente pela presença de aditivos e apresentaram valores de firmeza e adesividade de 2,54 N e 0,01 N, respectivamente. O MAP cozido apresentou 10,4 mg de cianidina-3-glicosídeo / 100 g (base seca), com redução de apenas 16% de antocianinas da massa crua. A análise sensorial com 100 provadores não treinados apresentou altos índices de aceitação (entre 67% e 89%) sendo sabor e textura os atributos mais bem avaliados que contribuíram para uma intenção de compra expressiva (86%) caso o produto estivesse disponível para venda. Foi possível reaproveitar um resíduo do processamento do arroz preto e desenvolver uma massa inovadora sem glúten de alta qualidade, com sabor peculiar de castanha, cor púrpura natural, com propriedades nutricionais, antioxidantes e por ser isenta de glúten, é um produto com potencial de benefícios e aumento da diversidade de alimentos para celíacos.
Palavras-chave: Subproduto do arroz-preto; Antocianinas; Macarrão; Qualidade tecnológica; Aceitabilidade do consumidor.

Resumen
En este estudio fue abordada la fabricación y caracterización de pasta sin gluten a partir de un subproducto del procesamiento industrial de granos de arroz negro. La pasta de arroz negro (PAN) fue extrusada en formato penne y desarrollada con harina de arroz negro: harina de arroz blanco 1:2 p/p, y aditivos alimentarios para mejorar la textura y propiedades viscoelásticas: almidón de tapioca, goma xantana, huevo y agua. Se evaluó la calidad de cocción, textura, color CIEL*a*b* y antocianinas monoméricas totales. El tiempo óptimo de cocción fue 7 minutos, la PAN tuvo 31,9 % de humedad, 68,0 % de absorción de agua y 4,8 % de pérdida por cocción. Las propiedades de textura se vieron afectadas positivamente por la presencia de aditivos y presentaron valores de firmeza y adhesividad de 2,54 N y 0,01 N, respectivamente. La PAN cocida presentó 10,4 mg de cianidina-3-glucósido/100 g (base seca), con reducción de solo 16% de antocianinas de la masa cruda. El análisis sensorial con 100 probadores no entrenados mostró alta aceptación (entre 67% y 89%) siendo el sabor y la textura los atributos mejor evaluados que contribuyeron a una intención de compra expresiva (86%) si el producto estuviera disponible para la venta. Se logró reutilizar un residuo del procesamiento del arroz negro y desarrollar una innovadora pasta de alta calidad, con peculiar sabor a castaña, color púrpura natural, con propiedades nutricionales y antioxidantes y, al ser libre de gluten, es un producto con beneficios potenciales y mayor diversidad de alimentos para celíacos.
Palabras clave: Subproducto de arroz negro; Antocianinas; Pasta; Calidad tecnológica; Aceptabilidad del consumidor.

1. Introduction

Black rice (*Oryza sativa* L.) is a variety of pigmented rice, characterized by its dark and bright color, and accentuated flavor of nuts, which is gaining space in the production and consumption of the Brazilian population. In addition to being phenotypically different from white or brown rice, it has the advantage of containing greater nutritional properties in its composition, such as higher contents of proteins, fibers, and bioactive compounds (Massaretto et al., 2022). The main bioactive compound found in black rice are the anthocyanins, classified as flavonoids, which confer the color of grain and play an important role in human health (Samyor et al., 2017). These phytochemicals are responsible for several positive health effects such as decreasing oxidative stress, preventing hypercholesterolemia and related metabolic syndromes (Aalim et al., 2021; Shao et al., 2018).

During rice processing are generates co-products, which represent 8 to 12% of processed rice. These co-products are consisted basically by rice husk, rice bran and broken grains, which are rich in nutritional components. However, these residues present a problem for industries due to the difficulties associated with the correct destination and costs, since only a few of them are used for animal feed and oil production. In this way, the use of agro-industrial by-products, such as black rice residues, such as black rice flour, can be not only a sustainable solution as it contributes to the reduction of the economic impacts resulting from its production, but also represents an alternative to add value to new products through its application as an ingredient in plant-based foods.

Black rice flour is one option for developing new products due to its high versatility and great potential for the development of foods with bioactive compounds that attend to a specific consumer, such as celiac individuals, who need a diet with gluten restriction (Scarton et al., 2021; Meza et al., 2020). Consumer presents a crescent interest not only for healthier food, but also for its practicality, low cost, and sensory attributes, which are all considered in purchase intention (Meza et al., 2019).

With a growing concern to trace health benefits and an expansion of the functional food market, an offer of innovative pasta has been explored in the scientific area and food industries. Although, several types of pasta have been developed from white and brown rice (Kong et al., 2012), and other cereals such as soy, beans, corn, quinoa, buckwheat, flaxseed, and sweet potato, the development of pasta based on black rice has not yet been explored. In this context, the objective of this work was to produce an innovative pasta from black rice byproduct and evaluate the physicochemical, nutritional, and sensory proprieties of uncooked and cooked pasta.

2. Methodology

2.1 Sampling

The black rice flour (*Oryza sativa* L.) (80 mesh) was obtained from Ruzene Industry, located in Pindamonhangaba, São Paulo, Brazil. Black rice flour results from black rice processing, which are characterized as agro-industrial by-product. Samples were stored in plastic bottles at 4˚C ± 2˚C protected from light until use.

2.2 Pasta production and cooking parameters

For the gluten-free pasta preparation were used white rice flour, black rice flour, tapioca starch flour, xanthan gum, salt, whole egg, and water as described in Table 1. The formulation used results from several preliminary tests to achieve adequate cohesiveness and elasticity, allowing the extrusion process. The use of additives for the formulation of pasta, such as tapioca starch, xanthan gum and egg can improve its viscoelasticity, allowing the pasta to acquire better malleability and texture properties, resulting in a consistent product after cooking and a better appearance.

Table 1 – Formulation of black rice pasta.

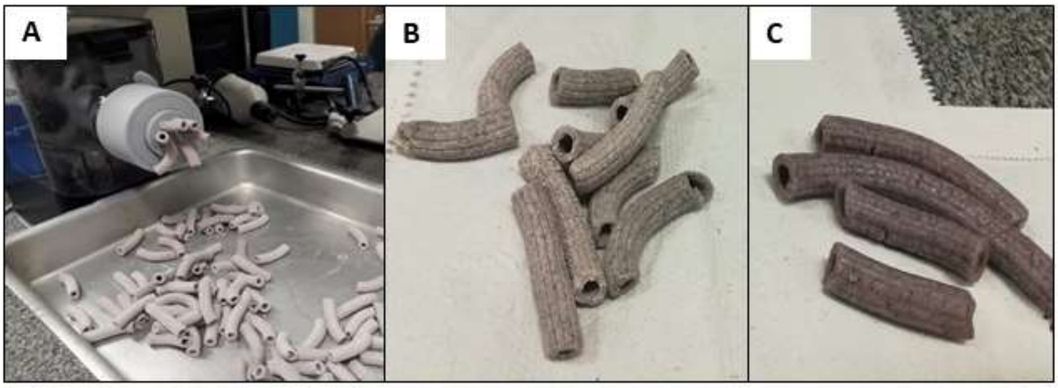
Ingredients	Quantity (g)	Proportion (%)
White rice flour	120	32,0
Black rice flour	65	17,3
Tapioca starch flour	60	16,0
Xanthan gum	5	1,3
Salt	5	1,3
Whole egg	45	12,0
Water	75	20,0
Total	375	100

Source: Authors (2022).

The ingredients were extruded in a homemade extruder (Pasta Maker, RI2335, Philips-Walita, Brazil) with a capacity of 200 to 400 g and the proportion of solid and liquid ingredients was 2.5:1 (w:v). The dry ingredients were mixed uniformly in a bowl, while in another bowl, the egg was manually beaten for 1 minute, and water was added, then incorporated into the dry mixture in the extruder. The dry mixture was added to the mixing chamber of the extruder and turned on in automatic mode, in which the liquid mixture was slowly added by opening the lid. The process of batching and extrusion of the dough takes about a total of 20 minutes. After hydration, homogenization, and kneading, the dough was extruded in an automatic fresh dough machine through the screw, molded and cut by the cutting die (penne type), with a length of 4 cm and an internal diameter of 1 cm, being collected in a stainless-steel container at the exit of the matrix.

Black rice pasta obtained was cooked in boiling water (pasta: water, 1:6, w/v) at 98ºC. The cooking time was defined as seven minutes to obtain a cooked pasta, with adequate texture and soft central part, as recommended by Leitão (1990). Immediately after the cooking time, the dough was drained and immersed in cold water to stop the cooking (Figure 1).

Figure 1 – Extrusion of pasta from black rice byproduct (A), the visual appearance of raw pasta (B) and cooked pasta (C).



Source: Authors (2022).

2.3 Physicochemical properties

2.3.1 Cooking time

The pasta cooking time was adjusted after the water started to boil and the pasta was added, waiting again for the water to boil with the pasta. The optimal cooking time was evaluated based on the adaptation of the cooking method proposed by Silva et al. (2009). Samples of pasta were removed from the cooking at intervals of 6, 7, and 8 minutes. These samples were placed between two Petri glass plates, and a central white line was observed to disappear when pressed, thus defining the optimal cooking time. The cooking time was counted only by observing the re-boiling of the water after adding the pasta. Subsequently, the pasta was removed from the cooking and cooled in 600 mL of water at room temperature (25°C) for 1 minute to stop its cooking.

2.3.2 Water absorption capacity

The water absorption capacity (A) was evaluated through the difference between the weight of the raw pasta (P1) and the weight of the cooked pasta after draining the cooking water (P2), following by Equation 1.

$$A\ (\%) = \frac{(P2 - P1)}{P2}\ x100 \qquad \textit{Eq. 1}$$

2.3.3 Swelling volume

The swelling volume (V) of the pasta was determined by drying the cooked samples in an oven (TE-394/2, Tecnal, Brazil) at 105°C for 4 hours and placed in the desiccator for 30 min, requiring the sample to be replaced in the oven for another 1 hour until they obtained constant weight. The porcelain capsule and the cooked mass were previously weighed. After these procedures, the swelling volume in grams of water/grams of dry pasta was calculated, through the difference between the weight of the cooked pasta (P3) and the weight of the dry pasta (P4), according to Equation 2.

$$V = \frac{P3 - P4}{P4} \quad \textit{Eq. 2}$$

2.3.4 Solids loss

The percentage of solids loss (S) was calculated based on the cooking water of 100 grams of fresh black pasta, which was reserved in a bowl and its weight recorded, and then placed for drying in an oven (TE-394/2, Tecnal, Brazil) for 12 hours, then the residues after drying were weighed. Thus, the loss of solids was calculated by the fraction between the weight of residues after drying (P5) over 100 grams of fresh mass (P6) on an analytical balance, according to Equation 3.

$$S\,(\%) = \frac{P5}{P6} x100 \quad \textit{Eq. 3}$$

2.3.5 Texture analysis

Texture profile was evaluated in a texturometer (Brookfield Engineering Laboratories, CT3-50K, Middleboro, USA) connected to a computer containing data analysis software (Texture Pro Software, CT. V1.2 Build 9, Brookfield Engineering Laboratories, Middleboro, USA). Samples with 4 cm length were positioned precisely in the center of the texturometer, using a 35 mm cylindrical probe, configured with 2 compression cycles, the time between cycles of 0 s, trigger force of 0.07 N, target compression start distance of 5 mm (50% of initial thickness) and initial and return compression velocity of 1 $mm.s^{-1}$. At least 10 measurements were performed in triplicate.

2.3.6 Instrumental color

Instrumental color was measured according to AACC (2000), method 14-22, using a portable colorimeter (Konica Minolta CR-400, Osaka, Japan), calibrated, and standardized to operate with the following specifications: observation angle of 2° and illuminant D65. The color attributes L*, a* and b* were evaluated, with the chromaticity coordinate a* indicating the trend in the region from red (+a*) to green (-a*), the chromaticity coordinate b* indicating the direction of color from yellow (+b*) to blue (-b*) and L* indicating the brightness from white (L*=100) to black (L*=0). The CIE L*a*b coordinates were obtained on the surface of the pasta cooked at 10 random points on the surface of the pasta. Measurements were made in triplicate and readings were taken at 10 different points for each sample.

2.4 Nutritional properties

2.4.1 Nutritional value

The levels of energy, carbohydrate, protein, fat, saturated fat, trans fat, fiber, and sodium were calculated by indirect analysis, using values from the nutritional information tables contained in the ingredients used. The percentage of the daily value of each component was calculated according to the table of reference daily values of nutrients of mandatory declaration (Brasil, 2003).

2.4.2 Total anthocyanins

For the extraction of total anthocyanins (TAC), 1 g of black rice flour was mixed with 50 mL acidified methanol (methanol:1 N HCl (85:15 v/v) in triplicate, and the absorbance (*A*) of the solution was measured at 535 nm (Meza et al., 2020). TAC was calculated according to Equation 4, and the results were expressed as mg equivalent cyanidin-3-*O*-glucoside per 100 g of sample.

$$TAC = {A \times MW \times V \times 10^5}/{\varepsilon \times WS} \quad \textit{Eq. 4}$$

where: *MW*, the molecular weight of cyanidin-3-*O*-glucoside (449 g/mol); *V*, the total volume of anthocyanin extract (L); *ε*, the molar absorptivity of cyanidin-3-*O*-glucoside (25.965 L.mol/cm); and *WS*, sample weight (g).

2.5 Sensory evaluation

The sensory analysis of black rice-based pasta was conducted with 100 untrained panelists. Allergic individuals or those who disliked any ingredient used in the formulation were excluded. Each taster received a sample of approximately 20g of cooked black rice pasta. A separate bottle of tomato sauce was available to each taster to add to the pasta and a glass of water to clean the taste buds and the evaluation form. The black rice pasta was evaluated for visual appearance, color, odor, flavor, texture and overall acceptability. Panelists were asked to score the samples according to a 7-point hedonic scale (7 = like extremely to 1 = dislike extremely). For purchase intention, a 5-point hedonic scale was used (5 = would certainly buy to 1 = would certainly not buy). The Research Ethics Committee of the Federal University of São Paulo, under decision number 89881818.2.0000.5505, approved this study.

2.6 Statistical analysis

All data were expressed as mean ± standard error of at least three replicates. Significant differences between samples were evaluated by one-way ANOVA (p<0.05), the Student's *t* test, or Tukey's test using Minitab 19.2 (Minitab Inc., PA, USA).

3. Results and Discussion

3.1 Phytochemical properties of black rice pasta

Cooking quality is one of the most important attributes to acceptance by consumers. The optimal cooking time obtained was 7 minutes, which resulted in an appropriate texture of the pasta. Several studies related cooking time from 5 to 13 minutes for pasta preparation (Piwińska et al., 2016; Larrosa et al., 2016; Padalino et al., 2013; Huang & Lai, 2010). The optimal cooking time value is affected by the starch gelatinization temperature of the flour, shape, and dimensions of the dough. Kong et al. (2012) prepared pasta using wheat flour:black rice flour in the proportions of 98:2, 95:5, 90:10 and 85:15 (w/w), and the average cooking time found was 5 minutes. Piwińska et al. (2016), made a penne-shaped pasta from a semolina-based formulation (durum wheat) enriched with oat fiber, dehydrated by different drying processes (conventional oven and vacuum) and the optimal cooking times ranged from 7 to 13.5 minutes. In this work, the physicochemical, textural and color parameters of the raw and cooked black rice pasta were shown in Table 2.

Table 2 – Black rice pasta's physiochemical, texture and color parameters.

	Raw black rice pasta	Cooked black rice pasta
Physiochemical parameters		
Moisture (%)	31.95±0.30[b]	64.74±0.10[a]
Water absorption capacity (%)	67.88±2.11	-
Solids loss (%)	4.78±0.42	-
Swelling index (g H_2O/g pasta dry basis)	1.84±0.01	
Texture atributes		-
Firmness (N)		2.54±0.12
Adhesiveness (mJ)		0.01±0.05
Resistance (N)		0.51±0.03
Cohesiveness (N)		0.16±0.05
Instrumental color		
L*		45.51±0.40
a*		7.75±0.11
b*		2.28±0.10

Values are means of at least three replicates ± standard errors of values. For texture and color analysis, n=10. Different letters in the line indicate statistically significant differences (*p*<0.05). Source: Authors (2022).

Raw black rice pasta showed moisture content of 31.95%, while the cooked black rice pasta was 64.74%. Kong et al. (2012) presented similar values of moisture (31.95%) for the raw pasta based on a mixture of wheat and black rice in the proportion of 85:15 (w/w). However, it is worth mentioning that the proportion used in this work between white rice flour and black rice flour was 2:1 (w/w). According to Kong et al. (2012), the increase in the content of black rice flour can increase the moisture of the mixture.

Raw black rice pasta showed a solid loss of 4.78%, similar solid loss value (3.47%) was found by Kong et al. (2012) in the pasta containing 15% black rice flour. The loss of solids is related to the loss of formulation components by dissolution or the detachment of the gelatinous starch matrix during the cooking process. In this process part of the starch material is transferred to the cooking water, which can result in a soft and sticky product depending on the percentage of loss (Marti & Pagani, 2013). According to Ormenese & Chang (2005) excellent quality pasta should not have a solids loss of more than 6%, intermediate quality between 6 and 8% and low quality more than 10%. It was also observed that the cooking water was slightly purple, which also characterizes a partial loss of anthocyanin compounds. The swelling index (1.84 g of H_2O/g of pasta) and water absorption (67.88 %) values obtained in this work were similar to those found by Kong et al. (2012) 1.7 to 1.8 g of H2O/g of pasta and 63.8 to 67.9%, respectively.

The texture parameters analyzed were firmness, adhesiveness, resistance, and cohesiveness. The firmness parameter (2.54 N) is mainly influenced by the cooking quality, in which an increase in the cooking time would change the pasta volume and consequently its firmness would decrease. The reduction in solids loss to the cooking water results in a firmer product by keeping its components in an intact and non-solubilized state, such as starch, which is characteristic of undergoing gelatinization, which changes the physical structure of the product (Huang & Lai, 2010). Adhesiveness (0.01 N) is related to the amount of amylose released in the pasta, especially when there is an increase in the cooking time, causing the pasta to have a "sticky" appearance. The decrease in this parameter is linked to an optimal proportion between the processes of starch gelatinization and protein network formation (Larrosa et al., 2016). The resistance (0.51 N) of the noodles demonstrates the ability to resist an initial deformation and remain unchanged. The use of additives, such as egg, changes the viscoelastic properties, providing better consistency and cohesiveness (Padalino et al., 2011). The cohesiveness parameter (0.16 N) is related to how unique and intact the sample is under cooking, a parameter that confers resistance to second deformations in order to the product to remain in its entirety, such as during cooking, without breaking its structure in the face of bubbling water, providing good stability (Thuengtung & Ogawa, 2020).

Black rice is characterized by the dark color, which makes it different from most products based on this grain. Color is also one of the main attributes to be evaluated in a sensory analysis, which can influence the judgment of product acceptance, becoming a major challenge in the development of new products. One of the benefits of producing black rice derivatives is the fact that the product contains natural pigments, which not only improve and differentiate the sensory aspect of special foods, but also increase their nutritional quality (Kong et al., 2012). The L* parameter varies from 0 to 100 and determines the luminosity of the sample, where values close to 0 present a completely dark color. The parameters a* and b* range from -60 to +60, where a* determines the color trend between green and red, and b* the color trend between blue and yellow, respectively. The analyzed black rice pasta has relatively low values that characterize a dark color, which can probably be intensified with an increase in the content of black rice flour. This fact can lead to an increase in the amount of anthocyanins content, which corresponds to the main natural compound that provides pigmentation and shows antioxidant capacity.

3.2 Nutritional properties of black rice pasta

The nutritional values of the black rice pasta were estimated by calculation, through the nutritional information of each ingredient, considering their respective proportion in the dough formulation (Table 3).

Table 3 – Nutritional value of black rice pasta.

	Amount per 100g	**%DV***
Energy value (kcal)	270	14
Carbohydrates (g)	50	17
Proteins (g)	7.1	9
Total fat (g)	5.3	10
Saturated fat (g)	0.9	4
Trans fat (g)	0	**
Dietary fiber (g)	0.7	3

*% Daily Values based on a diet of 2000 kcal or 8400 kJ. Their values can be higher or lower depending on your energy needs. ** DV not established. Source: Authors (2022).

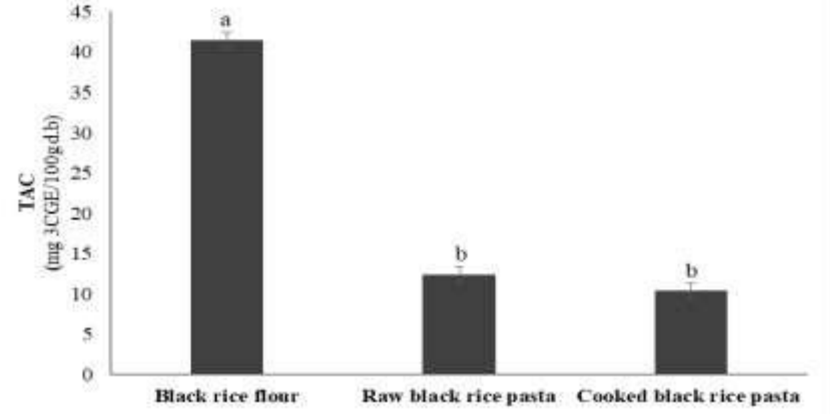
The energy value of black rice pasta was significantly lower than commercial brands, resulting in a less caloric food than traditional ones. The black rice pasta presented low amounts of carbohydrates (50%), this fact supports the claim that the pigmented variety of rice has a lower amount of starch, consequently a lower amount of amylose, contributing to a better texture profile for the pasta and a decrease in the glycemic index. The total fat content (5.3%) was higher than in commercial brands and is related to the addition of egg to the formulation. The egg exerted a technological function of increasing the protein network in order to improve the viscoelastic properties, and the presence of lecithin contributed to the emulsification. On the other hand, its addition can increase the values of total fat and cholesterol.

The amount of proteins and dietary fiber in black rice pasta was 7.1 and 0.7%, respectively. Meza et al. (2020) described protein and fiber contents of 10.59 and 6.30% in raw black rice, respectively. The amount of fiber and protein found in this work can be explained by the fact that black rice pasta was made from a by-product of the milling and processing of the black rice grain. In this way, a considerable loss of fiber and protein can occur due to the industrial processing that results in broken grains and grains that suffer the loss of parts of the pericarp, which are the predominant grain fraction of the dietary fibers. It is important to point out that gluten-free foods intended for people with celiac disease must be produced under conditions without risk of cross-contamination to ensure food safety for their consumers and present clear and correct information on package labels so that celiac disease patients can trust and have new options in your gluten-free diet (Pinto et al., 2020).

In addition to the nutritional quality, the content of total anthocyanins content (TAC) of the black rice flour, and the raw and cooked black rice pasta were also analyzed (Figure 2). Anthocyanins play an important role in health benefits such as reducing chronic diseases (Hao et al., 2020). Black rice flour showed a 41.5 mg of cyanidin-3-glycoside/100 g sample in dry basis. Meza et al. (2020) described the value of 559.41 mg of cyanidin-3-glycoside/100 g sample in whole black rice flour. The lower amount found is a result of commercial black rice grain processing, as the highest concentration of this bioactive compound is mainly found in the rice bran portion (Massaretto et al., 2022). Therefore, black rice flour has only residues, such as broken grains and those that have lost part of the bran and/or pericarp, reducing the content of anthocyanins.

The extrusion processing significantly affects the TAC content by reducing 4-fold its level in black rice pasta (12.4 mg of cyanidin-3-glycoside/100 g sample) as can be observed at Figure 2. However, considering that black rice flour represented only 17.3% in the formulation of gluten-free pasta (Table 1) the contents of anthocyanins found were very expressive. The stability of anthocyanins is influenced by temperature, presence of metals, oxygen, pH, and light (Massaretto et al., 2022; Flores et al. 2022), conditions submitted in the pasta extrusion process that could cause a decrease in its content. However, no differences were observed after the cooking processing of black rice pasta (10.4 mg of cyanidin-3-glycoside/100 g sample). Although anthocyanins undergo degradation at temperatures above 25°C (Massaretto et al., 2021), the anthocyanins of black rice pasta maintained stable at the pasta cooking temperature. Hiemori et al. (2009) observed that the degradation of anthocyanins is related to the presence of protocatechuic acid, a cyanidin fragment, which corresponds to the deglycosylation product of anthocyanins. During cooking, there is an increase in the amount of protocatechuic acid, which degrades anthocyanins. Additionally, Hiemori et al. (2009) explain that the cooking method also alters TAC levels, reporting that cooking rice at low temperatures resulted in greater retention of TAC content than using a high-temperature and pressure. This information suggests that the degradation of anthocyanins derives from the thermal processes and the cooking time to which they are exposed (Hiemori et al., 2009). This work deserves to show that an innovative product from the by-product of black rice can be nutritive and rich in anthocyanins that are associated with antioxidant capacity compared to the traditional pasta in the market.

Figure 2 – Total anthocyanin contents of black rice flour, and raw and cooked black rice pasta.



Values are means of at least three replicates ± standard errors of values. Different letters in the column indicate statistically significant differences (p<0.05). C3GE, cyanidin-3-glycoside. Source: Authors (2022).

3.3 Sensory evaluation of black rice pasta

Black rice pasta is an unconventional pasta that is not available for commercialization in the market. This innovative food product highlighted for being a gluten-free product, naturally colored, containing xanthan gum and tapioca starch. As it is a product that did not have any reference in the gustatory memory of consumers, sensory analysis was a fundamental tool to know the consumers' acceptance of the new product (n = 100). It was decided to do not to compare the black rice pasta with any conventional pasta (wheat-based), nor with a "control" (white rice pasta), nor with commercial brown rice pasta so that the panelists had total concentration and focus on analyzing the sample individually, in order to assess its potential of acceptance. Among the 100 tasters, 63% were women and 37% were men, aged between 20 and 67 years, and 93% of them did not have the habit of consuming gluten-free pasta.

The sensory evaluation of black rice pasta was evaluated to color, flavor, taste, texture, and visual aspect (Table 4). The positive evaluation of the black rice pasta was surprising, showing the great potential of this new product in the market. The literature mentions that acceptance rates above 70% are considered promising, indicating a good acceptability of the product (Dutcoski, 2007). Of the attributes evaluated, flavor (89.2%), texture (85.7%) and overall impression (83.3%) were the ones that received the best qualifications on the hedonic scale. Several tasters reported a pleasant and smooth flavor, different from conventional pasta. Possibly what contributed to the different flavor was the presence of black rice flour, which has a slightly accentuated flavor of walnuts or chestnuts, as the other formulation ingredients had a neutral flavor. The odor attribute (78.3%) also presented an extremely positive result, with reports of chestnut smell. The attributes of visual appearance (68.7%) and color (67.3%) were the ones with the lowest acceptability, but even so they were values very close to the ideal (above 70%). Consumers are used to consuming white or slightly yellowish pasta, so it was expected that their acceptance would be lower due to the unusual purple color that leads to distrust on the part of the consumer. Changes in habits of a widely consumed food are quite resistant, but the high acceptability of black rice pasta among the consumers suggests that this new product could be accepted and inserted into the diet.

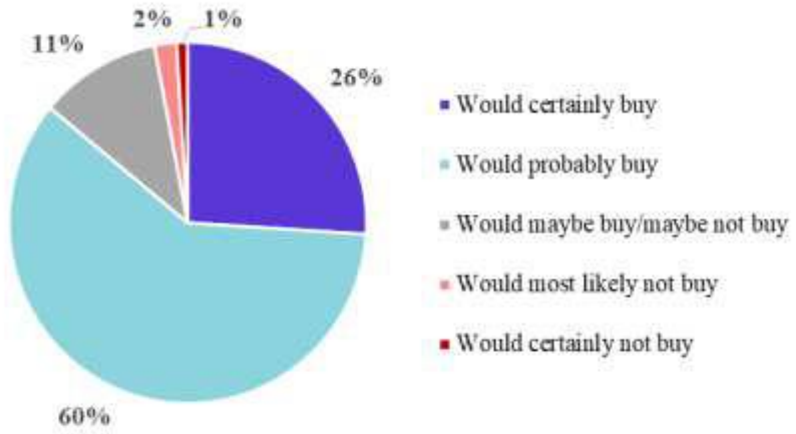
Table 4 - Sensory properties of the cooked black rice pasta.

	Cooked black rice pasta	**Acceptability index (%)**
Color	4.70±1.50	67.3
Flavor	5.50±1.11	78.3
Taste	6.12±0.90	89.2
Texture	6.00±1.10	85.7
Visual aspect	4.88±1.40	68.7
Overall acceptability	5.86±0.95	83.8

Values are means of 100 untrained assessors' ± standard errors of the values. 7-point hedonic scale (7 = like extremely to 1 = dislike extremely) was applied. Source: Authors (2022).

The purchase intention of black rice pasta was presented in Figure 3. This analysis indicated that 26% of the panelists would certainly buy the product and 60% might buy it, 86% of those evaluated showed interest in acquiring the black rice pasta, characterizing a significantly high purchase intention for an innovative functional product with a differentiated appearance, being able to compete in the gluten-free pasta market. Regarding the products' price, it is estimated that black rice pasta would be close to commercial gluten-free pasta due to its raw material originates from a residue from the processing of black rice.

Figure 3 - Purchase intention of black rice pasta evaluated by tasters.



Source: Authors (2022).

4. Conclusion

The black rice pasta based on black rice by-product of the processing of industrial black rice grain addressed in this study showed to be a new product with great technological, nutritional, and sensory characteristics. As black rice flour was the reuse of industrial waste, it was possible to transform the by-product into a profitable raw material with special functional properties and naturally colored. Black rice pasta showed the advantage of being gluten-free, less caloric and containing low contents of carbohydrates in its composition when compared to traditional pasta. Furthermore, the incorporation of residues of black rice in the formulation of pasta improved the total dietary fiber and anthocyanins contents, which are associated with preventing several chronic diseases due to its antioxidant capacity. The sensory analysis resulted in the products' great acceptance, in which the parameters of flavor, texture and overall acceptability received the highest approval from the tasters. The purchase intention of black rice pasta also showed a great result, indicating that more than 86% has interesting to buy the pasta. Future research can explore other formats of gluten-free black rice-based pasta, increase the proportion of black rice flour, and investigate more combinations with other ingredients as source of proteins and fibers.

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