



NUTRITIONAL CHARACTERIZATION, COLOR PROFILE, PHENOLIC AND FLAVONOID CONTENT OF CRIOLO BEAN (*PHASEOLUS VULGARIS* L.) CULTIVATED IN THE SOUTHERN AGRESTE OF PERNAMBUCO

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ABSTRACT

Objective: The objective of this study was to characterize, for the first time, the nutritional value, phenolic and flavonoid compound profile, and coloration of the landrace bean variety *Fogo na Serra* (*Phaseolus vulgaris* L.), cultivated in the Agreste Meridional region of Pernambuco, Brazil, aiming to highlight its functional potential and socioeconomic importance.

Materials and Methods: Proximate composition analysis, instrumental color determination, and quantification of total phenolics and flavonoids were performed following AOAC (2016), Singleton *et al.* (1999), and Dewanto *et al.* (2002) methodologies. Samples were cultivated under controlled agroecological conditions, harvested, lyophilized, and stored for laboratory analysis.

Results and Discussion: The beans showed 20.64% protein, 69.08% carbohydrates, 4.12% ash, 1.17% lipids, and 4.99% moisture, indicating high nutritional density. The ash content exceeded that of widely consumed commercial varieties, suggesting a higher mineral concentration, possibly linked to soil composition or genetic traits. The intense dark-red coloration ($L^* = 41.33$; $a^* = 12.5$; $b^* = 6.73$) correlated with high total phenolic and flavonoid contents, compounds known for their antioxidant capacity and potential to reduce oxidative stress. Compared to carioca and black beans, *Fogo na Serra* presented higher carbohydrate and mineral levels, while maintaining protein values within the typical range for *Phaseolus vulgaris*. These bioactive compounds, including anthocyanins and proanthocyanidins, are associated with protective effects against metabolic disorders, cardiovascular diseases, and certain cancers. The combination of nutritional richness and bioactive content positions this variety as a promising functional food.

Research Implications: Findings reinforce the relevance of conserving and promoting landrace beans for dietary diversification, nutritional security, and biodiversity preservation.

Originality/Value: This is the first scientific report on *Fogo na Serra*, unveiling its unique nutritional and functional profile, which may encourage further research, sustainable cultivation, and inclusion in health-oriented food strategies.

Keywords: Food, Sustainable agriculture, Phytochemicals, Coloring agents.

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CARACTERIZAÇÃO NUTRICIONAL, PERFIL DE COR, TEOR FENÓLICOS E FLAVONOIDES DO FEIJÃO CRIOULO (PHASEOLUS VULGARIS L.) CULTIVADO NO AGRESTE MERIDIONAL DE PERNAMBUCO

RESUMO

Objetivo: O objetivo deste estudo foi caracterizar, pela primeira vez, o valor nutricional, o perfil de compostos fenólicos, flavonoides e coloração da variedade crioula de feijão Fogo na Serra (*Phaseolus vulgaris* L.), cultivada no Agreste Meridional de Pernambuco.

Materiais e Métodos: Foram realizadas análise centesimal, determinação instrumental de cor e quantificação de fenólicos totais e flavonoides, seguindo metodologias da AOAC (2016), Singleton *et al.* (1999) e Dewanto *et al.* (2002). As amostras foram cultivadas e processadas em condições controladas.

Resultados e Discussão: O feijão apresentou 20,64% de proteínas, 69,08% de carboidratos, 4,12% de cinzas, 1,17% de lipídios e 4,99% de umidade, valores que indicam alta densidade nutricional. O teor de cinzas superou o de variedades comerciais, sugerindo maior concentração mineral. A coloração vermelho-escura intensa ($L^* = 41,33$; $a^* = 12,5$; $b^* = 6,73$) correlaciona-se com elevados teores de fenólicos totais e flavonoides, compostos reconhecidos por suas propriedades antioxidantes e protetoras contra doenças crônicas. Comparações com feijão carioca e preto revelaram maior teor de carboidratos e minerais, mesmo que com proteínas ligeiramente inferiores, se mantendo dentro da faixa nutricional típica. A presença de compostos sugere potencial funcional relevante, alinhado a estudos que relacionam o consumo de feijões pigmentados à prevenção de doenças metabólicas, cardiovasculares e degenerativas.

Implicações da Pesquisa: Os achados reforçam a importância de valorizar variedades crioulas na diversificação alimentar, segurança nutricional e preservação da biodiversidade.

Originalidade/Valor: Este é o primeiro estudo científico sobre o feijão Fogo na Serra, revelando atributos nutricionais e funcionais que podem estimular pesquisas, cultivo e consumo sustentável.

Palavras-chave: Alimentos, Agricultura sustentável, Compostos fitoquímicos, Pigmentos.

CARACTERIZACIÓN NUTRICIONAL, PERFIL DE COLOR, CONTENIDO FENÓLICO Y FLAVONOIDE DEL FRIJOL CRIOLO (PHASEOLUS VULGARIS L.) CULTIVADO EN AGRESTE SUR DE PERNAMBUCO

RESUMEN

Objetivo: El objetivo de este estudio fue caracterizar, por primera vez, el valor nutricional, el perfil de compuestos fenólicos y flavonoides, y la coloración de la variedad criolla de frijol *Fogo na Serra* (*Phaseolus vulgaris* L.), cultivada en el Agreste Meridional de Pernambuco, Brasil.

Materiales y Métodos: Se realizaron análisis de composición centesimal, determinación instrumental de color y cuantificación de fenoles totales y flavonoides, siguiendo las metodologías de la AOAC (2016), Singleton *et al.* (1999) y Dewanto *et al.* (2002). Las muestras fueron cultivadas y procesadas en condiciones controladas.

Resultados y Discusión: El frijol presentó 20,64% de proteínas, 69,08% de carbohidratos, 4,12% de cenizas, 1,17% de lípidos y 4,99% de humedad, valores que indican alta densidad nutricional. El contenido de cenizas superó al de variedades comerciales, lo que sugiere una mayor concentración mineral. La intensa coloración rojo oscuro ($L^* = 41,33$; $a^* = 12,5$; $b^* = 6,73$) se correlaciona con altos niveles de fenoles y flavonoides totales, compuestos reconocidos por sus propiedades antioxidantes y efectos protectores contra enfermedades crónicas. Las comparaciones con frijoles carioca y negro revelaron mayor contenido de carbohidratos y minerales, incluso con valores de proteína ligeramente inferiores, manteniéndose dentro del rango nutricional típico. La presencia de compuestos bioactivos sugiere un potencial funcional relevante, en consonancia con estudios que relacionan el consumo de frijoles pigmentados con la prevención de enfermedades metabólicas, cardiovasculares y degenerativas.

Implicaciones de la Investigación: Los resultados refuerzan la importancia de valorar las variedades criollas para la diversificación alimentaria, la seguridad nutricional y la preservación de la biodiversidad.



Originalidad/Valor: Este es el primer estudio científico sobre el frijol *Fogo na Serra*, que revela atributos nutricionales y funcionales que pueden fomentar la investigación, el cultivo y el consumo sostenible.

Palabras clave: Alimentos, Agricultura sostenible, Fitoquímicos, Colorantes.

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1 INTRODUCTION

Abstract: The common bean (*Phaseolus vulgaris* L.) is a legume that plays an important role in the agricultural and food sectors, being predominantly cultivated in regions of temperate and subtropical climate. Its production and consumption are fundamental for food security and the livelihood of millions of people in different countries, especially in Brazil, with importance in both the nutritional and socioeconomic context (Corzo-Ríos *et al.*, 2020; Balensifer, 2019).

Since the nineteenth century, beans have been present in the Brazilian diet, consolidating itself as an indispensable component of the population's meals. Its cultural relevance can be observed in several traditional preparations, such as the *baião de dois*, typical of the Northeast region, and the *bean tutu*, traditional in the South. These recipes reflect the cultural specificities and sensory preferences of each region of the country, always having beans as a central ingredient (Barrigossi *et al.*, 2021).

From a nutritional point of view, beans are among the most important sources of vegetable protein, also providing complex carbohydrates, high dietary fibre content and low lipid content (Oliveira *et al.*, 2018). This composition gives the grain a nutritional profile of high quality, making it especially valued in diets aimed at promoting health and preventing chronic diseases.

In addition to the macronutrient composition, beans are recognised for their high concentration of bioactive compounds, such as polyphenols, flavonoids and tannins, which contribute to their antioxidant activity and their potential protective effects against inflammatory and degenerative processes. According to the Food and Agriculture Organisation of the United Nations (FAO), the regular consumption of this legume is associated with the reduction of the risk of metabolic and cardiovascular diseases, with benefits attributed to the synergy between essential nutrients and bioactive phytochemicals (FAO, 2021; Jones, 1999; Rodríguez Madrera *et al.*, 2020). In addition, they exhibit anti-inflammatory, antihypertensive, antiaging and chemoprotective effects, being associated with the inhibition of the development



of different types of cancer, including colon, oesophagus, lung, breast and liver (Bento *et al.*, 2021).

In several traditional communities, such as those of the Brazilian Northeast, it is common for families to maintain their own agricultural practices, cultivating their food and sharing lifestyles and cultural values over generations. These activities *are characterised by low environmental impact and contribute to the maintenance of genetically diverse varieties, preserving local seeds grown for thousands of years* (Medeiros, 2019; Barrigossi *et al.*, 2020; Fischer *et al.*, 2016). Part of these varieties, including different types of beans, are conserved in the Active Germplasm Bank of the Agronomic Institute of Pernambuco (IPA), in Recife, Pernambuco.

Understanding the nutritional value of landraces represents an opportunity to promote the sustainable use of food resources. In this context, the present study aimed to elucidate, for the first time in the scientific literature, the nutritional value of a creole variety of beans grown by agricultural communities in the Southern Agreste of Pernambuco, in addition to determining the colour and quantifying the levels of phenolics and flavonoids

2 MATERIALS AND METHODS

2.1 PLANT MATERIAL AND SAMPLE PROCESSING

The bean seeds were obtained through a partnership with the IPA's Active Germplasm Bank, which supplied the variety Fogo na Serra (*Phaseolus vulgaris*). Its cultivation took place between November 2022 and January 2023, at the IPA Experimental Station, located at 09°01'09" South latitude, 36°34'07" West longitude and 780 metres above sea level. After harvest, the seeds were sun dried, threshed and transported to the Federal Rural University of Pernambuco (UFRPE), where they were sanitised and subjected to lyophilisation (Terroni, LS3000) for approximately 24 hours. Finally, they were stored in labelled bags and kept at -18 °C in a freezer until analysis.



2.2 CENTESIMAL ANALYSIS

Through the centesimal analysis, the nutritional value of the beans was determined. The protein content was determined according to the AOAC (2016) procedures, the protein content was quantified by the Kjeldahl method, and the lipid content was obtained by extraction using a chloroform-methanol mixture (2:1). The carbohydrate content was calculated by difference. In addition, moisture was obtained by drying in an oven at 105 °C to constant weight and ashes by muffle furnace incineration at 550 °C.

2.3 COLOUR ANALYSIS

Grain colour was evaluated using a Minolta CR-400 colourimeter (Minolta Konica, Japan). The analysis followed the CIELAB system (Commission Internationale de l'Éclairage, 1976), in which L* indicates the luminosity, a* represents the position on the red-green axis and b* refers to the blue-yellow axis. Five readings were performed to consider the variability, and subsequently the averages of L *, a * and b * were calculated, allowing the evaluation of the colour.

2.4 PREPARATION OF THE EXTRACT FOR ANALYSIS OF PHENOLICS AND FLAVONOIDS

For the preparation of the extract for the analysis of phenolic compounds and flavonoids, the methodology described by Fogaça *et al.* (2012) was followed. In summary, methanol acidified with 1.4 mL of hydrochloric acid was used for each 0.5 g of beans. The sample was submitted to sonication in an ultrasonic disruptor (Ultronique) for 10 minutes, in order to promote microfractures in the material. Then, the samples were centrifuged (SOLAB, SL-708) at $2,500 \times g$ for 10 minutes. After this step, the supernatant was filtered on filter paper using a funnel, and the filtrate was collected in a 50 mL volumetric flask, completing the volume to the meniscus with the same initial solution.

2.5 ANALYSIS OF PHENOLIC AND FLAVONOID CONTENT

The total phenolic content was determined by the Folin-Ciocalteu method (Singleton *et al.*, 1999). Briefly, 0.5 mL of the extract was diluted in distilled water and reacted with the



Folin-Ciocalteu reagent, followed by the addition of sodium carbonate to stabilise the reaction. After incubation for 60 minutes, at room temperature and in the absence of light, the absorbance was measured at 725 nm in a spectrophotometer (SPECTRUM SP-2000UV), using a white prepared without the extract. The results were expressed in milligrammes of gallic acid equivalents (GAE) per 100 g of dry weight of the seeds, based on a calibration curve.

The total flavonoid content was determined according to the method described by Dewanto *et al.* (2002), with modifications. The extract was diluted in water and treated sequentially with a solution of sodium nitrite, aluminium chloride and sodium hydroxide, allowing incubation periods between the additions for the reactions to occur. The absorbance was measured at 510 nm in the same spectrophotometer, and the results were expressed in milligrammes of catechin equivalents per gramme of dry weight, based on a calibration curve.

2.6 STATISTICAL ANALYSIS

All analyses were performed in triplicate technique, and the results are presented as mean $\pm$ standard deviation. No inferential statistical analyses were performed because the evaluation was conducted in a single sample.

3 RESULTSS AND DISCUSSÕES

3.1 CENTESIMAL COMPOSITION

The proximate composition of Fogo na Serra beans, presented in Table 1, showed a moisture content of 4.99%, proteins of 20.64%, lipids of 1.17%, ashes of 4.12% and carbohydrates of 69.08%. When comparing with data from the Brazilian Table of Food Composition (TBCA) for the most consumed beans in Brazil, it is observed that the moisture content of Fogo na Serra is considerably lower than the 12% reported for carioca beans and the 13.3% for black beans, indicating a drier sample, possibly due to the drying process or the environmental conditions of the growing region (Wander, 2025; TBCA, 2023).



Table 1

Centesimal composition of Fogo beans in the Serra.

Variety	Humidity (%)	Ash (%)	Carbohydrates (%)	Protein (%)	Lipids (%)
Sierra fire	4,99 ± 0,05	4.12 ± 0.17	69.08% ± 0.75	20,64 ± 0,01	1,17 ± 0,02

The protein content of Fogo na Serra was slightly lower than that of carioca beans (22%) and black beans (22.4%), according to TBCA, but still within the common range for common beans. This small variation can be attributed to genetic variability and specific agroecological conditions of the varieties, which influence protein metabolism and nutrient accumulation. The relevant protein content reinforces the potential of this bean as a source of quality vegetable protein, important for balanced diets and for populations seeking alternatives to animal proteins (Pastrana-Pastrana, 2024).

The lipids in Fogo na Serra showed a lower value than carioca beans (1.87%) and slightly lower than black beans (1.28%). Although lipid levels are generally low in beans, this difference may reflect adaptations of the variety to the region. In relation to the ash content, Fogo na Serra presented a higher value than carioca beans (3.67%) and black beans (3.93%), suggesting a higher mineral concentration. This finding is in agreement with the results of a study by Lovato *et al.* (2018), which reported an ash content of 3.43% for the traditional variety BRS Esplendour. This may indicate a soil rich in minerals or greater absorption capacity by the plant, a characteristic valued in traditional varieties for its differentiated nutritional potential (Embrapa, 2023).

As for the carbohydrate content, Fogo na Serra presented a higher value than carioca beans (60%) and black beans (59.1%), which can be explained by the lower humidity and the reduction in protein and lipid contents, since carbohydrates constitute the main energy fraction of the grain (FAO, 2019). Recent studies have shown that polysaccharides derived from common bean (*Phaseolus vulgaris* L.) can exert significant hypoglycemic effects. In a study published by Qu *et al.* (2024), the heteropolysaccharide CIE2-F, isolated from beans, showed a significant reduction in hyperglycemia, improvement in insulin resistance and positive modulation of the lipid profile, in addition to promoting the balance of the intestinal microbiota favourable to metabolic health in diabetic mice. These findings suggest that, in addition to its energy function, bean carbohydrates may contribute to glycemic control and prevention of metabolic diseases, such as type 2 diabetes.

In addition, the valorisation of traditional beans opens the way for innovations in the food industry, such as the production of protein flours, snacks and bioactive extracts. The



highest mineral concentration and carbohydrate composition can be exploited for the development of products with improved nutritional attributes, adding economic value to the agricultural communities that grow these varieties (Patil, 2025).

The results obtained for the Fogo creole bean in the Serra show potential as a nutritionally rich source, with characteristics that make it promising for food diversification and food security.

3.2 PHENOLIC CONTENT, FLAVONOIDS AND COLOURATION

Through Table 2, it was possible to observe that the levels of total phenolic compounds and flavonoids in the analysed bean presented values close, indicating that a significant portion of the phenolics may be constituted by flavonoids. The colouration of the beans, as seen in Figure 1 and 2, visually as reddish with a hue that approximates purple, reinforces this relationship, since flavonoids, especially anthocyanins and flavonols, are responsible for pigmentation in red, purple and bluish tones in legumes (Martins *et al.*, 2020; Xu *et al.*, 2022; Wang, 2025).

Figure 1

Beans Fire in the Sierra.

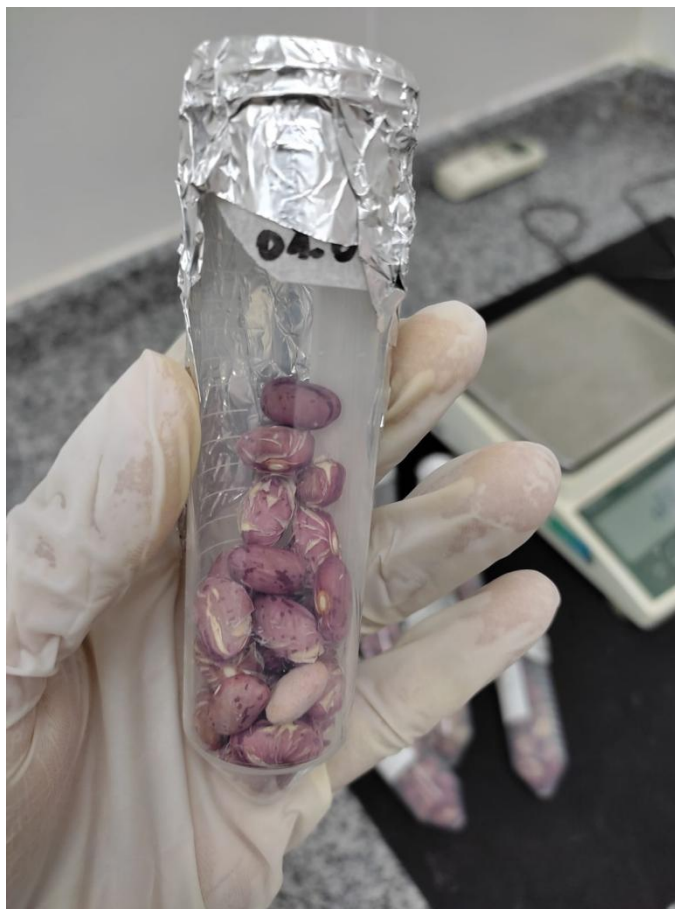


Source: Adapted from Creole Seed Network of Agreste de Pernambuco, 2019.



Figure 2

Beans Fire in the Sierra lyophilised.



The instrumental analysis of colour by the CIELAB system showed values of $L^* = 41.33$, $a^* = 12.5$ and $b^* = 6.73$. The relatively low value of L^* indicates a dark colour, characteristic of grains with a high concentration of pigments. The high a^* shows the predominance of intense red hues, while the b^* suggests the presence of subtle yellow subtones. The combination of these parameters gives the bean a dark red hue, consistent with the presence of anthocyanins and proanthocyanidins, compounds often related to high levels of total phenolics and high antioxidant activity.

Previous studies have shown that beans with intensely pigmented integument have significantly higher concentrations of phenolic compounds and flavonoids compared to lighter-coloured varieties (Silva *et al.*, 2021). Thus, the results indicate that the colour observed in the beans studied can serve as a visual marker of the presence of these bioactive compounds, highlighting their functional potential and their value as antioxidant food.



4 CONCLUSION

The present study presented, for the first time, the nutritional characterisation of the creole variety of *Fogo* beans in the *Serra*, cultivated in the Southern Agreste of Pernambuco, Brazil. The results revealed a seed with balanced proximate composition, highlighting the high carbohydrate content and relevant protein concentration, as well as a higher proportion of ash compared to varieties widely consumed in Brazil, suggesting higher mineral potential. The significant presence of phenolic compounds and flavonoids, associated with the intense dark red colour, indicates a functional potential that must be elucidated, contributing with positive health implications due to the antioxidant and protective properties attributed to these phytochemicals.

The appreciation of this traditional variety, grown in sustainable and low-scale agricultural systems, contributes to the preservation of biodiversity, the strengthening of food security and the recognition of local varieties. In addition, the results open perspectives for the insertion of *Fogo na Serra* in strategies aimed at health promotion.

Therefore, encouraging the research, cultivation and marketing of landraces such as *Fogo na Serra* represents not only an investment in nutrition and public health, but also an act of cultural and environmental preservation.

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