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ORIGINAL ARTICLE

Physicochemical characterization of fresh and germinated bean and cowpea varieties[1]

Caracterização físico-química de variedades de feijões in natura e germinados

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HIGHLIGHTS:
The germination process is viable and efficient in increasing bioactive and nutritional compounds.
The maximum protein content in fresh beans was 27.21% (cowpea); in germinated beans, it reached 48.60% (cowpea).
The increase in the content of total phenolic compounds in germinated beans ranged between 30.12 and 32.94%.

ABSTRACT: Beans are a vital component of the human diet, being able to supply a large part of the daily protein requirements of individuals, in addition to containing considerable amounts of iron, calcium, vitamins, carbohydrates, fiber, and lysine. Controlled germination is an accessible and effective technique that aims to improve the nutritional, functional, and sensory qualities of seeds intended for food consumption. This study aimed to characterize fresh and germinated beans of *Phaseolus vulgaris* (carioca, branco, preto, gordo varieties) and *Vigna unguiculata* (cowpea). The germination process was conducted in trays containing the sand substrate (350 g) in the environmental conditions of the laboratory. The fresh and germinated beans were evaluated for physicochemical variables in triplicate. The germination process increased moisture content, water activity, ash, pH, soluble alcohol acidity, proteins, ascorbic acid, phenols, tannins, flavonoids, anthocyanins, and carotenoids. On the other hand, there was a reduction in the content of lipids, starch, and total sugars in bean seeds. With the increase in bioactive compounds, it was found that the germination process is an excellent method for increasing the nutritional quality of beans.

Key words: *Phaseolus vulgaris*, *Vigna unguiculata*, nutritional quality

RESUMO: O feijão é um importante componente da dieta humana, sendo capaz de suprir grande parte das necessidades proteicas diárias dos indivíduos, além de conter quantidades consideráveis de ferro, cálcio, vitaminas, carboidratos, fibras e lisina. A germinação controlada é uma técnica acessível e eficaz que visa melhorar as qualidades nutricionais, funcionais e sensoriais de sementes destinadas ao consumo alimentar. O objetivo deste estudo foi caracterizar feijão *Phaseolus vulgaris* das variedades carioca, branco, preto, gordo e feijão-caupi (*Vigna unguiculata*) in natura e germinado. O processo de germinação foi realizado em bandejas contendo substrato areia (350 g), em condições ambientais de laboratório. Em seguida, os grãos in natura e germinados foram avaliados quanto às variáveis físico-químicas em triplicata. A germinação do feijão aumentou o teor de umidade, atividade de água, cinzas, pH, acidez álcool solúvel, proteínas, ácido ascórbico, fenóis, taninos, flavonóides, antocianinas e carotenóides. Por outro lado, houve redução no teor de lipídios, amido e açúcares totais nas sementes de feijão. Com o aumento dos compostos bioativos, constatou-se que o processo de germinação é um excelente método para aumentar a qualidade nutricional do feijão.

Palavras-chave: *Phaseolus vulgaris*, *Vigna unguiculata*, qualidade nutricional

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Introduction

Beans are cultivated almost all over the world, and approximately 130 countries grow the legume to supply internal and external trade; Brazil is the third largest producer, with 11% of the world's total production of preto, colored, and cowpea beans (Paraná, 2020).

The dry mass of bean seeds contains 20 to 30% proteins, which is why this legume represents an important component of the human diet, containing considerable amounts of iron, calcium, vitamins, carbohydrates, fiber, and lysine (Lemes, 2018).

Germination is one of the oldest, simplest, and most economically viable process that aim to improve the nutritional value of beans. During germination, starch degradation and an increase in total protein content occur due to the conversion of other seed components in addition to phenolic compounds (Andressa et al., 2023).

Considering the biochemical processes that occur during the germination activity of seeds, the study of germination kinetics is essential for the gradual monitoring of changes in the seed's original nutritional and bioactive compounds. Additionally, knowledge about the germination process and the substances capable of improving it is of great relevance in botanical studies, as well as the environmental and physiological factors capable of influencing seed germination to improve the management of native species of the biome (Nobrega et al., 2018).

Furthermore, Amadeu et al. (2021) state that both germinated beans and their respective flours have the potential to enrich food products with essential nutrients. Thus, this study could positively impact the fight against malnutrition, a global issue that significantly affects many countries where beans are a staple food in the population's diet.

Given the above, the present study aimed to characterize fresh and germinated beans of *Phaseolus vulgaris* (carioca, branco, preto, gordo varieties) and *Vigna unguiculata* (cowpea).

Material and Methods

The raw materials used were beans from two species, *Phaseolus vulgaris* L. (Preto, Branco, Carioca, and Gordo varieties) and *Vigna unguiculata* (L.) Walp. (Cowpea). All beans used were obtained from local stores in Campina Grande, Paraíba (7° 13′ 51″ S and 35° 52′ 54″ W).

The beans were transported to the Laboratory of Storage and Processing of Agricultural Products (LAPPA) of the Agricultural Engineering Academic Unit (UAEA) of the Center of Technology and Natural Resources (CTRN) of the Universidade Federal de Campina Grande (UFCG). They were then selected for physical quality and integrity, and beans that presented mechanical injuries, poor appearance, and visible defects were discarded. The beans were then sanitized to remove dirt and impurities and prevent the proliferation of fungi by immersing them in a sodium hypochlorite solution (100 mg L^{-1}) for 10 minutes and finally rinsed in running water.

The germination process was conducted in trays containing sand (350 g) as substrate, exposed to laboratory environmental conditions of temperature (25 °C) and relative humidity (70%), and wetted with distilled water daily (using 200 mL of water for each tray). The amount of water used was established through previous tests. The sand used was sterilized in an oven at 170 °C.

Preliminary germination tests were conducted at times 0, 24, 48, 72, and 96 hours, then the time of 96 hours was selected based on the best results concerning phenolic compounds.

Hundred fresh and germinated beans were characterized in triplicate according to the following physicochemical variables (on dry weight basis): water content according to AOAC (2016); water activity by direct reading at 25 °C, using Aqualab equipment, model 3TE, from Decagon Devices; ash, pH, soluble alcohol acidity, lipids, proteins, and total sugars according to the methodology proposed by AOAC (2016); reducing sugars by the methodology proposed by Miller (1959); starch and ascorbic acid according to AOAC (2016); phenolic compounds by the method of Folin and Ciocalteu (Waterhouse, 2006); tannins according to the methodology described by AOAC (2016); anthocyanins and flavonoids according to methodologies described by Francis (1982); chlorophyll and carotenoids using the methodology described by AOAC (2016).

The data analysis was performed in a completely randomized design with analysis of variance and the Tukey test at $p \leq 0.05$, using Assistat software version 7.7 Beta (Silva & Azevedo, 2016).

The choice not to directly compare varieties was deliberate, as each variety may have unique characteristics that could introduce variability in the results when compared directly. Focusing on the comparison within each variety ensured that any differences observed between fresh and germinated beans were attributable to the sprouting process and not to intrinsic genetic differences between the varieties.

Results and Discussion

Table 1 contains the mean values and standard deviations of water content, water activity, ash content, pH, soluble alcohol acidity, lipids, and proteins of fresh and germinated beans from different species and varieties. As expected, it was observed that after germination, the water content increased in the beans of all species and varieties, with values ranging between 90.94 and 97.28% (dry base). Given these values, it is clear that it is necessary to conduct some processes to preserve germinated beans, and one of the most used processes is drying (Mendonça et al., 2015).

It can be seen that the water content of fresh beans ranged from 9.68% (Carioca beans) to 13.84% (dry base) (preto bean) (Table 1). In general, the optimal range of bean water content for storage is between 11 and 13% (dry base); by keeping the water content of the seeds below 13%, the respiratory process remains low, prolonging the maintenance of the quality of the stored product (Cavalcante, 2020).

The water activity of fresh beans ranged from 0.374 (Carioca beans) to 0.436 (branco beans) and of germinated beans from 0.826 (gordo beans) to 0.880 (preto beans), also showing an increase with the germination process and presenting high values, which are not recommended considering that in substrates with low water activity, the microbial metabolism

Table 1. Mean values and standard deviations of water content, water activity, ash content, pH, soluble alcohol acidity, proteins, and lipids of fresh and germinated beans from different species and varieties

	Varieties				
	Preto	Branco	Carioca	Cowpea	Gordo
			Water content (% - dry base)*		
Fresh	13.84 ± 1.49 b	13.23 ± 0.54 b	9.68 ± 0.87 b	12.93 ± 1.13 b	12.65 ± 1.54 b
Germinated	97.28 ± 0.48 a	94.68 ± 0.89 a	90.94 ± 0.72 a	99.37 ± 0.95 a	93.17 ± 1.13 a
			Water activity*		
Fresh	0.418 ± 0.003 b	0.436 ± 0.001 b	0.374 ± 0.009 b	0.420 ± 0.003 b	0.413 ± 0.002 b
Germinated	0.880 ± 0.003 a	0.853 ± 0.002 a	0.862 ± 0.008 a	0.842 ± 0.001 a	0.826 ± 0.002 a
			Ash content (% - dry base)*		
Fresh	4.76 ± 0.03 b	3.73 ± 0.03 b	4.16 ± 0.02 b	3.37 ± 0.08 b	4.12 ± 0.22 b
Germinated	9.10 ± 0.03 a	7.99 ± 0.17 a	7.73 ± 0.10 a	6.31 ± 0.26 a	8.27 ± 0.25 a
			pH*		
Fresh	6.23 ± 0.01 b	6.36 ± 0.01 b	6.30 ± 0.01 b	6.33 ± 0.01 b	6.39 ± 0.02 b
Germinated	6.65 ± 0.03 a	6.50 ± 0.02 a	6.61 ± 0.02 a	6.74 ± 0.02 a	6.79 ± 0.01 a
			Soluble alcohol acidity (% - dry base)*		
Fresh	1.95 ± 0.26 b	1.63 ± 0.26 b	1.49 ± 0.26 b	1.63 ± 0.26 b	1.34 ± 0.00 b
Germinated	2.58 ± 0.45 a	2.04 ± 0.44 a	1.75 ± 0.43 a	2.35 ± 0.00 a	2.02 ± 0.44 a
			Lipids (% - dry base)*		
Fresh	3.38 ± 0.03 a	2.74 ± 0.30 a	2.93 ± 0.14 a	2.30 ± 0.08 a	3.33 ± 0.37 a
Germinated	1.55 ± 0.01 b	1.49 ± 0.03 b	1.54 ± 0.02 b	1.49 ± 0.04 b	1.26 ± 0.03 b
			Proteins (% - dry base)*		
Fresh	21.90 ± 0.10 b	25.86 ± 0.87 b	21.21 ± 0.38 b	27.21 ± 0.37 b	20.97 ± 0.60 b
Germinated	42.66 ± 0.17 a	44.90 ± 0.77 a	44.31 ± 0.12 a	48.60 ± 0.85 a	36.86 ± 0.07 a

*Means followed by the same lowercase letter in the columns do not differ statistically by the Tukey test at $p \leq 0.05$

present is interrupted, with inhibition of their development and reproduction (Amadeu et al., 2021).

The increase in water content and water activity with germination is commonly reported, according to Sritongtae et al. (2017), in rice beans (*Vigna umbellata*) and Rosa-Millán et al. (2019), in preto beans (*Phaseolus vulgaris* L.).

It was verified that all species and varieties had a significant increase in ash content with germination. The ash content of fresh beans varied between 3.37% (cowpea beans) and 4.76% (dry base) (preto bean). Similar values were verified in the study on the chemical composition of different types of fresh beans, with an ash content of 4.60% for preto beans and 3.90% for Carioca beans (Los et al., 2018).

In germinated beans, ash contents ranged between 6.31 and 9.10% (dry base), with the highest content also observed in preto beans and the lowest in Cowpea beans, following the behavior observed in fresh beans.

When comparing the ash content between fresh and germinated beans, an increase in the ash content in germinated beans is observed in the order of 91.18% for preto beans, 114.21% for branco beans, 85.82% for Carioca beans, 87.24% for cowpeas, and 100.73% for gordo beans. In this way, it can be seen that the ash content practically doubled in germinated beans compared to fresh beans.

Machado et al. (2009) highlight the importance of the phytase enzyme. This seed constituent undergoes activation after seed hydration and promotes the reduction of phytic acid levels through hydrolysis, resulting in increased mineral availability.

It was verified that there was a difference between the pH of fresh and germinated beans for all varieties, so fresh beans had the lowest pH values (6.23 to 6.39), and germinated beans had the highest values (6.50 to 6.79). Similar values and also an increase in pH were verified by Marquezi (2016) for preto beans (cultivar SCS204 Predileto) fresh (6.54 to 6.56) and germinated (6.76 to 6.90) from different municipalities of Santa Catarina (Chapecó and Guatambu). Furthermore, in the same study, an increase in this parameter was observed for all germination temperatures tested, which was attributed to the generation of nitrogen compounds with lower molar mass during germination.

It can be seen that there was also an increase in soluble alcohol acidity with germination in all varieties, with percentage increases varying between 17.45 and 50.75%. It was observed that fresh beans had the lowest levels of soluble alcohol acidity, varying between 1.34% (gordo beans) and 1.95% (preto beans), and germinated beans presented the highest values ranging between 1.75% (Carioca beans) and 2.58% (preto bean).

It was verified that there was a reduction in lipid content with germination in all varieties, with percentages of decrease varying between 35.22 and 62.16%. This reduction may be related to the fact that the germination process requires energy for seedling formation. Hydrolytic enzymes are activated during this process, promoting the breakdown of large molecular substances, such as lipids and proteins, into smaller molecular compounds (Moongngarm & Saetung, 2010). Opposite performance was observed by Benevides et al. (2019) for beans from the pigeon pea (*Cajanus cajan* L.) and mangalô (*Phaseolus lunatus* L.) varieties, grown in Peru, with levels before and after germination, respectively, of 1.36 and 1.97% for pigeon pea beans, and 0.64 and 0.66% for mangalô beans.

It was observed that the opposite performance to that of lipids occurred for proteins, with an increase in protein contents with germination in all varieties (Table 1). Seed germination provides an improvement in nutritional value due to better protein digestibility, in addition to the reduction of antinutritional factors. It is expected that the protein content increases with germination since, during this process, enzymatic protein synthesis occurs, in addition to changes in composition that follow the degradation of other constituents (Martinez et al., 2011).

In fresh beans, proteins ranged from 20.97 (gordo beans) to 27.21% (cowpea beans), and germinated beans ranged from 36.86 (gordo beans) to 48.60% (cowpea), confirming that this legume has a high protein content (minimum of 12%). The percentage increase in the protein content of germinated beans was in the order of 73.63 to 108.91%.

A similar effect was also observed by Machado et al. (2009) for green mung beans with protein content between 29.22% (fresh) and 40.18% (germinated), for preto mung beans between 25.26% (fresh) and 39.08% (germinated), and dwarf pigeon pea between 22.54% (fresh) and 36.70% (germinated).

Mean values and standard deviations of the content of total and reducing sugars, starch, and ascorbic acid of fresh and germinated beans from the different species and varieties are shown in Table 2. The reduction in sugar contents occurs because germination is a pre-digestion process, where nutrients are assimilated for the growth of the embryo. One of these nutrients is starch, which is synthesized into glucose and fructose that are used in the respiration of the embryo and the synthesis of new molecules and cellular structures.

The total sugars of fresh beans ranged from 2.36 to 3.28%, and germinated ones from 1.12 to 1.53%. Zhu et al. (2017) stated that this increase in sugar content in germinated beans can be attributed to increased enzymatic activities leading to the hydrolysis of complex carbohydrates into simple sugars.

Low values for reducing sugars in beans were found, with significant differences between the averages for fresh and germinated beans only for the carioca, cowpea, and gordo beans.

Wongsiri et al. (2015) observed a significant increase in reducing sugars during germination of mung bean (*Vigna radiata*). Li et al. (2014) suggested that the increase in reducing sugar content during seed germination occurs mainly due to the increase in cellulose glucose through the metabolic reaction, which justifies the results obtained in this study.

As with total sugars, starch content decreased significantly with the germination process in all varieties. The starch content varied between 44.18 and 50.29% for fresh beans and 21.30 to 24.24% for germinated beans (Table 2).

The reduction in starch content with the germination process was also verified by Rosa-Millán et al. (2019), in which the starch content was limited from 35.1 g 100g^{-1} in fresh samples to 27.2 g 100g^{-1} after the germination of preto bean seeds (*Phaseolus vulgaris* - São Luís variety).

This reduction, during germination, is the result of the breakdown of starch by α-amylase, the main enzyme responsible for this degradation, which converts the starch into oligosaccharides or monosaccharides, which will be used in seed respiration and the synthesis of new cellular constituents (Xu et al., 2019).

A significant increase was verified in the ascorbic acid content with germination for the different varieties. The ascorbic acid contents of fresh beans ranged from 3.24 to 6.42 mg 100g^{-1}; in germinated beans, it ranged from 4.35 to 8.42 mg 100g^{-1} (Table 2).

According to Silva et al. (2014), during the seed germination process, antioxidants are produced, such as ascorbic acid, among others, thus increasing the antioxidant capacity of the seeds thus promoting greater health benefits with their consumption.

Mean values and standard deviations of the content of total phenolic compounds, tannins, total flavonoids, total anthocyanins, and total carotenoids of fresh and germinated beans from different species and varieties are shown in Table 3. Following the same behavior as ascorbic acid, total phenolic compounds are increased with germination in all bean species and varieties. The total phenolic compounds of fresh beans ranged from 817.21 mg of gallic acid 100g^{-1} (branco) to 949.42 mg gallic acid 100g^{-1} (preto), and in germinated beans from 1078.34 mg gallic acid 100g^{-1} (branco) to 1242.65 mg gallic acid 100g^{-1} (preto).

The values for total phenolic compounds are higher than those presented by Ampofo & Ngadi (2020), who analyzed ultrasound-assisted phenolic elicitation during the germination of common beans (*Phaseolus vulgaris*), observing a value of 216.74 mg of gallic acid 100g^{-1} of total phenolics in germinated seeds, treated with 360 W ultrasound for 60 minutes, after 96 hours of germination.

Like total phenolic compounds, tannins increased with germination in all varieties. Preto beans had the highest concentrations of tannins, with 814.39 mg 100g^{-1} (fresh) and 1060.43 mg 100g^{-1} (germinated), and branco beans had the lowest concentrations, with 705.53 mg 100g^{-1} (fresh) and 924.90 mg 100g^{-1} (germinated) (Table 3). Lower tannin values were

Table 2. Mean values and standard deviations of total sugars, reducing sugars, starch, and ascorbic acid in fresh and germinated beans from different species and varieties

	Varieties				
	Preto	Branco	Carioca	Cowpea	Gordo
			Total sugars (% - dry base)*		
Fresh	2.62 ± 0.01 a	3.15 ± 0.001 a	2.36 ± 0.001 a	3.15 ± 0.003 a	3.28 ± 0.01 a
Germinated	1.15 ± 0.002 b	1.12 ± 0.001 b	1.32 ± 0.002 b	1.53 ± 0.001 b	1.25 ± 0.002 b
			Reducing sugars (% - dry base)*		
Fresh	0.02 ± 0.01 a	0.01 ± 0.00 a	0.06 ± 0.01 a	0.01 ± 0.00 b	0.01 ± 0.00 b
Germinated	0.02 ± 0.00 a	0.01 ± 0.01 a	0.05 ± 0.00 b	0.02 ± 0.01 a	0.02 ± 0.01 a
			Starch (% - dry base)*		
Fresh	47.66 ± 0.53 a	49.19 ± 0.48 a	45.62 ± 0.28 a	50.29 ± 0.16 a	44.18 ± 0.13 a
Germinated	23.21 ± 0.06 b	21.45 ± 0.16 b	21.30 ± 0.11 b	24.24 ± 0.07 b	21.71 ± 0.04 b
			Ascorbic acid (mg 100g^{-1} - dry base)*		
Fresh	3.24 ± 0.00 b	4.29 ± 0.00 b	6.42 ± 0.00 b	5.36 ± 0.00 b	3.93 ± 0.61 b
Germinated	4.35 ± 1.08 a	6.14 ± 1.07 a	8.42 ± 1.04 a	8.17 ± 1.09 a	5.48 ± 0.00 a

*Means followed by the same lowercase letter in the columns do not differ statistically by the Tukey test at $p \leq 0.05$

Table 3. Mean values and standard deviations of bioactive compounds in fresh and germinated beans from different species and varieties different varieties

	Varieties				
	Preto	Branco	Carioca	Cowpea	Gordo
			Total phenolics (mg gallic acid 100 g^{-1} - dry base)*		
Fresh	949.42 ± 6.22 b	817.21 ± 2.35 b	866.26 ± 0.78 b	922.88 ± 1.57 b	878.79 ± 3.14 b
Germinated	1242.65 ± 3.41 a	1078.34 ± 2.07 a	1145.57 ± 2.35 a	1226.84 ± 1.35 a	1143.50 ± 1.56 a
			Tannins (mg 100 g^{-1} - dry base)*		
Fresh	814.39 ± 5.11 b	705.53 ± 1.93 b	744.82 ± 0.64 b	792.33 ± 1.29 b	756.07 ± 2.58 b
Germinated	1060.43 ± 2.80 a	924.90 ± 1.70 a	979.43 ± 1.93 a	1047.70 ± 1.11 a	978.11 ± 1.28 a
			Total flavonoids (mg of rutin 100g^{-1} - dry base)*		
Fresh	4.31 ± 0.02 b	2.28 ± 0.02 b	4.90 ± 0.04 b	2.91 ± 0.04 b	4.20 ± 0.02 b
Germinated	7.74 ± 0.04 a	5.18 ± 0.04 a	10.73 ± 0.07 a	5.45 ± 0.22 a	7.78 ± 0.04 a
			Total anthocyanins (mg 100 g^{-1} - dry base)*		
Fresh	1.39 ± 0.03 b	0.85 ± 0.03 b	1.14 ± 0.02 b	0.80 ± 0.03 b	0.63 ± 0.02 b
Germinated	2.57 ± 0.08 a	1.75 ± 0.03 a	2.10 ± 0.07 a	1.66 ± 0.03 a	1.29 ± 0.06 a
			Total carotenoids (mg 100 g^{-1} - dry base)*		
Fresh	4.44 ± 0.09 b	0.95 ± 0.10 b	3.93 ± 0.03 b	2.20 ± 0.08 b	3.52 ± 0.08 b
Germinated	10.17 ± 0.09 a	7.50 ± 0.04 a	8.25 ± 0.17 a	6.72 ± 0.13 a	8.08 ± 0.05 a

*Means followed by the same lowercase letter in the columns do not differ statistically by the Tukey test at $p \leq 0.05$

quantified by Oliveira et al. (2023) for fresh cowpea cultivars BRS Inhuma with 153.60 mg gallic acid 100g^{-1} and BRS Aracê with 522.60 mg 100g^{-1}.

The percentage increase in tannin concentrations in beans with germination varied between 29.37 and 32.23%. Benevides et al. (2019), when studying beans of the pigeon pea and mangalô varieties grown in Peru, found that the germination process reduced the tannin content due to the metabolic activity present; however, the combination of germination with cooking produced a better result, indicating that in many cases, the use of just one method is not capable of obtaining desirable nutritional changes, such as removal of antinutritional factors present in the bean.

Fresh beans had the lowest contents of total flavonoids (2.28 to 4.90 mg of rutin 100g^{-1}), and germinated beans had the highest values (5.18 to 10.73 mg of rutin 100g^{-1}) (Table 3). Flavonoids are part of phenolic compounds, so it was also expected that the total flavonoids in beans would increase significantly with germination for all types of beans. Benevides et al. (2019) found similar behavior when analyzing samples of pigeon pea and mangalô beans after germination and dehydration and found that there was an increase in flavonoid concentrations in fresh beans (Pigeon pea: 17.03 mg 100g^{-1}; Mangalô: 12. 23 mg 100g^{-1}) after the germination and freeze-drying process (Pigeon pea: 39.09 mg 100g^{-1}; Mangalo: 40.52 mg 100g^{-1}). Fresh and germinated seeds represent a source of antioxidants, such as flavonoids; therefore, their consumption has great potential in promoting health benefits (Silva, 2014).

A significant increase was verified in the total anthocyanins of the beans with germination in all species and varieties. Fresh beans had the lowest contents of total anthocyanins (0.63 to 1.39 mg 100g^{-1}), and germinated beans had the highest values (1.29 to 2.57 mg 100g^{-1}) (Table 3).

Total anthocyanin values included in this range were found by Landim et al. (2016) when analyzing fresh cowpeas from different cultivars (1.02 to 2.20 mg 100g^{-1}). According to Nunes et al. (2022), the total anthocyanin content in beans varies according to the different cultivars and parts of the plant, and also due to genetic characteristics and cultivation practices.

A significant increase in the mean values of total carotenoids in germinated beans in all species and varieties was also observed. Fresh beans had the lowest levels of total carotenoids (0.95 to 4.44 mg 100g^{-1}), and germinated beans had the highest values (6.72 to 10.17 mg 100g^{-1}) (Table 3). Silva (2014) found similar behavior when identifying the increase in total carotenoid content depending on germination time for linseed and millet from different varieties, highlighting those high concentrations of carotenoids obtained through food intake are associated with reduced risk of diseases chronicles.

Conclusion

1. Germination of beans of all varieties caused an increase in moisture content, water activity, ash, pH, soluble alcohol acidity, proteins, ascorbic acid, phenolic compounds, tannins, flavonoids, anthocyanins, and carotenoids.
2. After the germination process, there was a reduction in the lipid, starch, and total sugar content in the bean varieties.
3. With the increase in bioactive compounds, it was found that the germination process is an excellent method for increasing the nutritional quality of beans, regardless of the variety used.

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