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Comparative study of the proximate composition, physical-chemical and technological properties of the Arabica coffee by-product bran (husk and pulp)

Estudo comparativo da composição centesimal, propriedades físico-químicas e tecnológicas do subproduto do café Arábica (casca e polpa)

Abstract

Brazil, the world's leading producer of Arabica coffee, generates significant solid by-products during processing. These by-products, typically discarded, represent a potential source of valuable nutrients for the food industry. Two main processing methods, dry and wet, yield distinct by-products: cascara (dry) and pulp (wet). These by-products have favorable nutritional and technological properties for food applications. This study aimed to evaluate the proximate composition (moisture, protein, fat, fiber, ash), physicochemical and technological properties of brans derived from Brazilian Arabica coffee by-products (harvests 2020-2022) obtained from both dry and wet processing methods. The results showed bran rich in dietary fiber (30-60%) and protein (8–11%), with low-fat content (0.66–5%). Additionally, the bran had promising physicochemical and technological properties for food use. These findings suggest that coffee by-products hold significant potential as sustainable food ingredient, promoting product enrichment and contributing to the coffee industry's overall sustainability.

Keywords: Coffee. Dietary fiber. Protein. Novel food Ingredient. Sustainable.

Resumo

O Brasil, maior produtor mundial de café Arábica, gera quantidades significativas de subprodutos sólidos durante o processamento. Esses subprodutos, geralmente descartados, representam potencial fonte de nutrientes valiosos para a indústria alimentícia. Existem dois métodos principais de processamento, seco e úmido, que geram subprodutos distintos: casca (seco) e polpa (úmido). Esses subprodutos possuem propriedades nutricionais e tecnológicas favoráveis para aplicações alimentícias. Este estudo teve como objetivo avaliar a composição centesimal (umidade, proteínas, lipídeos, fibras, cinzas), propriedades físico-químicas e tecnológicas de farelos derivados de subprodutos do café Arábica brasileiro (safras 2020-2022) obtidos a partir dos métodos de processamento seco e úmido. Os resultados mostraram farelos ricos em fibras alimentares (30-60%) e proteínas (8-11%), com baixo teor de gordura (0,66-5%). Além disso, os farelos apresentaram propriedades físico-químicas e tecnológicas promissoras para uso alimentar. Esses achados sugerem que os subprodutos do café possuem um potencial significativo como um novo ingrediente alimentar sustentável, promovendo o enriquecimento de produtos e contribuindo para a sustentabilidade da cadeia da indústria cafeeira.

Palavras-chave: Café. Fibra alimentar. Proteína. Novo ingrediente alimentar. Sustentável.

INTRODUCTION

Brazil is the world's largest producer of Arabica coffee, and its commercial importance has been steadily increasing. Coffee processing generates large amounts of agricultural by-products, which can account for 30 to 50% of the total weight of the coffee fruit produced.[1]

There are two main methods for processing coffee cherries: dry and wet . Dry processing involves coffee cherries' natural or artificial drying immediately after harvest. Once they reach about 12% moisture, the cherries are mechanically pulped, and the resulting by-product from this processing method is called cascara.[2]

Wet processing involves the removal of the outer parts of the fruit in a series of steps, including pulping, fermentation, washing, and drying. Pulping generates the most solid by-products and consists of removing the outer skin and pulp, which produces a by-product called pulp.[3,4]

It is necessary to adequately characterize this by-product to define appropriate processes for the valorization of coffee husks. Studies with these matrices show that coffee by-products contain nutrients such as proteins, dietary fibers, lipids, carbohydrates, and minerals, which can add value to food products.[4-6]

They can also be considered a source of bioactive compounds, such as polyphenols, tannins, chlorogenic acids, caffeine, and other compounds with functional properties.[6]

The agri-food industry is interested in efficient and low-cost strategies to reduce waste generated during the production of food matrices. Techniques such as dehydration and the transformation of by-products into flour and/or bran have proven to be effective alternatives for reducing their volume, and minimizing the occurrence of degradation reactions, which can make their use by the industry feasible. Additionally, the use of these by-products as food ingredients can help preserve the environment, as they generally require proper treatment for disposal.[7]

An important step in the possible use of by-products is to consider, in addition to their chemical composition, their technological properties. Evaluating the technological behavior of farinaceous and similar products makes it possible to verify the feasibility of incorporating these raw materials into different food products.[8]

Given the high production of Arabica coffee in Brazil and the consequent high generation of solid by-products, it is relevant to balance this production with the appropriate use and application of these coffee by-products. Therefore, this study aimed to evaluate the proximal, physicochemical composition and technological potential of solid Arabica coffee by-products arising from different processing methods and distinct harvests, for possible use as a food ingredient.

As far as we know, this is the first study to address these characteristics of Arabica coffee by-products from different processing methods (wet and dry), localization and harvests time.

MATERIALS AND METHODS

Samples

The Arabica coffee by-products were kindly provided by partner producers. The samples from Rio de Janeiro were collected in the city of São José do Vale do Rio Preto, located in the mountainous region of the state (Latitude: 22° 09' 05" S Longitude: 42° 55' 28" W Altitude: 615 m), being 2 (two) samples of coffee pulp obtained by wet processing, named RJ20 (harvest 2020) and RJ22 (harvest 2022). The samples from Minas Gerais were collected in the city of Machado (Latitude: 21° 40' 29" S Longitude: 45° 55' 11" W Altitude: 820m), being 2 (two) samples of coffee cascara obtained by dry processing, named MG20 (harvest 2020) and MG21 (harvest 2021), and in the city of Nepomuceno (Latitude: 21° 14' 09" S Longitude: 45° 14' 09" W Altitude: 840m), being 1 (one) sample of coffee cascara, named MG22 (harvest 2022).

The samples from Rio de Janeiro (RJ20 and RJ22), from the wet processing method, were collected and dried in a ventilated oven at a temperature of 55 °C for 72 hours. The samples from Minas Gerais (MG20, MG21, and MG22), as they are naturally dried, were only collected and stored with out thermal treatment. The samples were stored in hermetically sealed bags suitable for grains (Grainpro®) until the grinding stage. To obtain the bran, the by-products were ground using a domestic grinder (Mr.Coffee-IDS 57) and then sieved with a 850 µm opening tammis (20 mesh), stored in closed glass jars, protected from light, and kept in desiccators (at room temperature 21±2°C) until the moment of analysis.

The by-product samples were considered as bran because according to the specific requirements of IN MAPA nº 8 of June 2, 2005, to be considered flour, the product must be sieved and 95% must pass through a 250 µm opening tammis (60 mesh).[9] These by-product brans were called Coffee By-Product Bran (CBB).

Proximal Composition

Proximal composition analysis was performed in triplicate, except fibers content in duplicate. Moisture (method 012/IV); ash (method 018/IV); protein (method 036/IV) using 5.75 as conversion factor due to the presence of caffeine in the samples; lipid (method 032/IV), and carbohydrate by subtracting the sum of ash, lipid, proteins and fibers from 100% (Nifext method), all according to Instituto Adolfo Lutz.[10] Total dietary fiber was determined by the enzymatic-gravimetric method according to *Codex Alimentarius* (AOAC 2009.01).[11] The results on ash, lipids, proteins, fibers, and carbohydrates were presented on a dry basis.

Physico-Chemical Analysis

Total Titratable Acidity (TTA), Hydrogenionic Potential (pH), and Total Soluble Solids (TSS) were analyzed from CBB extracts adapted from Institute Adolfo Lutz.[10] The pH was measured with a calibrated Prolab digital pHmeter (model PHB-500).[10] TSS content was determined in a Nova portable digital refractometer (model NOS DR500) and expressed in °Brix.[10]

Colorimetric analysis was performed on CBB samples using a Gardner reflectance spectrophotometer (Color-View model). The CIELAB scale (reflectance, d/8, D65 and observer angle 10°) was used. From this analysis, the respective values of L* (luminosity), a* and b* (color coordinates) were obtained.

Technological Properties

To determine the technological properties of the brans, analyses of the Water Absorption index (WA), Oil Absorption index (OA), Water Solubility index (WS) and Swelling Volume (SV) were performed.[12,13]

The granulometric analysis of the CBB was adapted from the American Association of Cereal Chemists (method nº 66-20), each sieve was weighed after the vibratory action of the equipment, and the results expressed as a percentage of material retained in each sieve from the initial amount of material (25 g).[14]

Statistical Analyzes

The results were expressed as mean and standard deviation. Data were submitted to analysis of variance (ANOVA), and treatments were compared to each other at a 5% significance level ($p \leq 0.05$). Samples that differed statistically, were treated with *t* test to compare means, and Bonferroni correlation.

RESULTS AND DISCUSSION

Table 1 shows the proximate composition of the CBB samples studied in this work on a dry basis.

Table 1. Proximal composition of CBB according to the processing method (pulp and cascara) and harvest year. São José do Vale do Rio Preto-RJ and Machado-MG. 2022.

Parameters (%)	Wetprocessing		Dryprocessing		
	RJ20	RJ22	MG20	MG21	MG22
Moisture	12.19^{a} ±0.01	7.05^{b} ±0.05	12.95^{c} ±0.06	14.86^{d} ±0.16	13.20^{c} ±0.15
Ash	8.13^{a} ±0.09	9.78^{b} ±0.01	7.41^{c} ±0.05	5.96^{d} ± 0.03	6.10^{cd} ±0.33
Lipids	5.69^{a} ±0.11	3.25^{b} ±0.30	2.17^{c} ±0.25	1.56^{cd} ±0.35	0.66^{d} ±0.43
[a]Proteins	10.65^{a} ±0.22	11.62^{b} ±0.28	10.65^{a} ±0.25	8.61^{c} ±0.23	9.58^{d} ±0.25
Fibers	68.80^{a}± 0.12	55.87^{b}± 0.22	62.29^{c}± 0.02	41.29^{d}± 0.03	36.77^{e}± 0.02
[b]Carbohydrates	6.73^{a} ±0.35	19.48^{b} ±0.07	17.49^{c} ±0.32	42.58^{d} ±0.41	46.90^{e} ±0.47

Results are expressed as mean ± standard deviation.
Means with equal letters on the same line do not differ from each other by the Bonferroni correlation ($p \leq 0.05$).
Data on ash, lipids, proteins, fibers, and carbohydrates are expressed on a dry basis.
[a]Proteins were calculated using 5.75 as conversion factor.
[b]Carbohydrates were calculated by difference.
RJ20: sample from RJ, wet processing, harvest 2020; RJ22: sample from RJ, wet processing, harvest 2022; MG20: sample from Machado – MG, dry processing, harvest2020; MG21: sample from Machado – MG, dry processing, harvest 2021; MG22: sample from Nepomuceno – MG, dry processing, harvest 2022.

The moisture content among the CBB samples showed significant statistical difference between the different processing methods and within the same processing method, except for samples MG20 and MG22. The moisture content can be affected by the type of processing, climatic conditions during natural drying (dry processing), treatment of by-products before storage, and during storage conditions. In this study, the samples obtained by the wet method were subjected to artificial drying in the laboratory. Even under fixed conditions, the volume of the sample being dried directly interferes with the final moisture content, which explains the difference between the moisture percentages of the samples (RJ20 and RJ22).

According to Brazilian resolution, the maximum moisture content accepted for farinaceous and similar products is 15%. Therefore, even with variations between the CBB samples, these were within the required parameters.[15] Moisture content lower than 15% (farinaceous and similar) or below 12% (coffee beans) can positively impact these products, as it allows for longer shelf life and storage, disfavoring the chemical and physical reactions that could degrade these products.[16]

According to the study carried out by Gemechu,[17] coffee by-products present in their composition a percentage of total ash in dry basis varying between 3-7% for the cascara and 6-9% for the pulp, with potassium being the predominant mineral in all by-products, followed by magnesium, calcium, and phosphorus. All samples of coffee by-products analyzed in this study presented percentages within the range reported in the literature for this parameter.[2,3,17] Significant statistical differences ($p \leq 0.05$) were found in ash content for samples from the same processing method and between harvests, except for sample MG22, which did not differ statistically in this parameter compared to samples MG20 and MG21. The sample RJ22 (wet processing) had the highest percentage of total ash content. The variation found in ash content can be mainly explained by factors related to cultivation, such as soil type, climatic conditions during the harvest, and fertilization. These factors can directly influence the levels of minerals available in the food.[18]

Regarding the lipid content, the CBB samples showed a statistically significant difference, except for the MG21 sample, which did not differ statistically from the MG20 and MG22 samples. These results indicate that cascara has a lower lipid content than pulp. Gemechu[17] reports that in the cascara lipid composition predominates saturated fatty acids (61-69%), followed by unsaturated fatty acids (18-39%). This fatty acid composition may have a positive effect on the stability of this CBB, as it does not favor lipid oxidation during storage. According to the literature, cascara shows lipid percentages ranging from 0.5-3%, while pulp can show percentages ranging from 2-7%, which corroborates the results found in this study.[3,19,20]

Significant differences were found in protein content both concerning the harvests and the processing methods, except for the MG20 sample, which did not differ significantly from the RJ20. Janissen & Huynhy[6] reported cascara with protein content of approximately 9% and in pulp it can vary between 10-12%, similar values found in this study. Braham & Bressani[21] suggested that protein from coffee pulp has amino acid concentrations similar to soy flour, and higher than corn ones. Aspartic acid, glutamic acid, glycine, alanine, proline, and lysine are higher in coffee pulp than in corn and soy. Despite the differences in protein content, the CBB evaluated in the present study had higher protein contents than other flours from fruit by-products, such as mango (6.6%).[22]

Total dietary fibers of the CBB samples ranged from 36.77-68.80%, with statistically significant differences between all analyzed samples. This is expected since the external part of the fruit is composed by fibrous material, which generally contains non-digestible polysaccharides, such as cellulose, hemicellulose, and polyphenol lignin.[19,20] Turck et al.[2] found levels ranging from 33.2-37.1% for cascara samples, which corroborates the findings for samples MG21 and MG22. Santos et al.[19] reported a dietary fiber percentage of 60.5% for pulp, similar to the values found for by-products from the same processing method, RJ20 and RJ22. According to the Regulation on nutrition and health claims made on foods by the European Union Council (EC) nº. 1924/2006, a food can only be considered high in fiber when it contains at least 6g of fiber per 100g of product.[23] Given these results, coffee pulp and cascara can be considered a by-product highly rich in total dietary fibers.

Regarding carbohydrate content, significant differences were found among all analyzed samples. This may suggest that this macronutrient can be influenced by both the harvest and the processing method. Additionally, this content is directly impacted by analytical variations and errors that may have occurred during proximal composition analyses.[24]

Turck et al.[2] report that cascara can have levels of 30-40 % total carbohydrates in its composition. This is consistent with the values found for samples MG21 and MG22. However, the same was not verified for sample MG20.

Samples from the wet processing showed lower percentages of carbohydrates compared to samples from the dry processing, especially sample RJ20, which had a lower percentage in this parameter compared with the sample from the same processing method (RJ22). The differences in carbohydrate content may be related to the different climatic conditions of the harvests and cultivation locations. Meteorological events directly affect the metabolic processes of plants and define potential productivity, product quality, and possible damage to its composition.[25,26] The United Nations Environment Programme (UNEP)[27] noted that the past few years have been the hottest recorded since the 80s, highlighting 2020 with an increase of about

1.2°C above pre-industrial temperatures. Additionally, the World Meteorological Organization predicts a 20% probability that the temperature increase will exceed 1.5°C as early as 2024: "The speed at which temperatures are rising is alarming". Arabica coffee requires mild average annual temperatures between 18-21°C. Above 23°C, the development and maturation of the fruits are accelerated, resulting in quality losses and variations in their composition.[28]

The results of the physicochemical analysis of the CBB samples are presented in Table 2.

Table 2. Physicochemical composition of CBB (pulp and cascara). São José do Vale do Rio Preto-RJ and Machado-MG. 2022.

Parameters	Wet processing		Dry processing		
	RJ20	RJ22	MG20	MG21	MG22
[a]pH	6.31±0.01[a]	5.41±0.01[b]	5.09±0.02[c]	5.09±0.01[c]	5.1±0.06[c]
[b]TTA (mg/100g)	57.8±6.68[a]	160.37±0.0[b]	203.31±13.04[c]	202.47±12.99[c]	206.81±13.27[c]
[c]TSS (°Brix)	1.4±0.10[a]	1.9±0.20[b]	2.4±0.12[c]	1.8± 0.06[b]	1.6± 0.06[ab]
[d]L*	79.11	79.29	79.13	79.13	79.13
[e]a*	0.00	0.57	1.49	1.49	1.49
[f]b*	7.97	6.04	6.75	6.75	6.75

Results are expressed as mean ± standard deviation.
Means with equal letters on the same line do not differ from each other by the Bonferroni correlation ($p \leq 0.05$).
[a]pH: hydrogen potential; [b]TTA: titratable total acidity; [c]TSS: total soluble solids.
[d]L*: denotes the degree of lightness; [e]a*: +a indicates red; –a indicates green; [f]b*: +b indicates yellow; –b indicates blue.
RJ20: sample from RJ, wet processing, harvest 2020; RJ22: sample from RJ, wet processing, harvest 2022; MG20: sample from Machado – MG, dry processing, harvest 2020; MG21: sample from Machado – MG, dry processing, harvest 2021; MG22: sample from Nepomuceno – MG, dry processing, harvest 2022.

The pH values of the CBB samples ranged from 5.09 to 6.31. Hoseini et al.[29] reported a pH variation of 5.35 to 6.63 for cascara, which is within the range of values observed for samples RJ20 and RJ22, obtained by wet processing.

These pH values are related to the Titratable Acidity (TTA) parameter of the product. This can be observed for sample RJ20, which had a pH closer to neutrality and, consequently, a lower acidity value. Other samples had lower pH values and higher TTA values.

Samples from the dry processing method did not show any statistically significant difference in TTA. However, samples RJ20 and RJ22, even though they came from the same processing method and farm, showed a significant difference. This may be due to the fermentative and oxidative processes that can occur in the by-products of this processing method.

According to Velásquez & Banchón,[30] some factors can explain the differences found concerning acidity and pH parameters, such as stage of maturation of the fruits, place of origin, soil, harvesting conditions, as well as the type of processing used, associated with the fermentation process and oxidative that occurs due to the natural microbiota present in the samples subjected to the wet processing stages (harvesting, water and machinery). These factors can all influence the acidity levels of coffee by-products, as observed in the present study.

In this study, the ºBrix values found ranged from 1.4 to 2.4. Sancho et al.[31] compared, in their research, ºBrix values of Brazilian tropical fruit residues (range of 1.0 - 6.8) in relation to their pulp (range of 8.4-20.6).

Considering that fruit pulps have a high sugar content, this may indicate low levels of sugar in the residues, as well as in the CBB samples evaluated in this research.

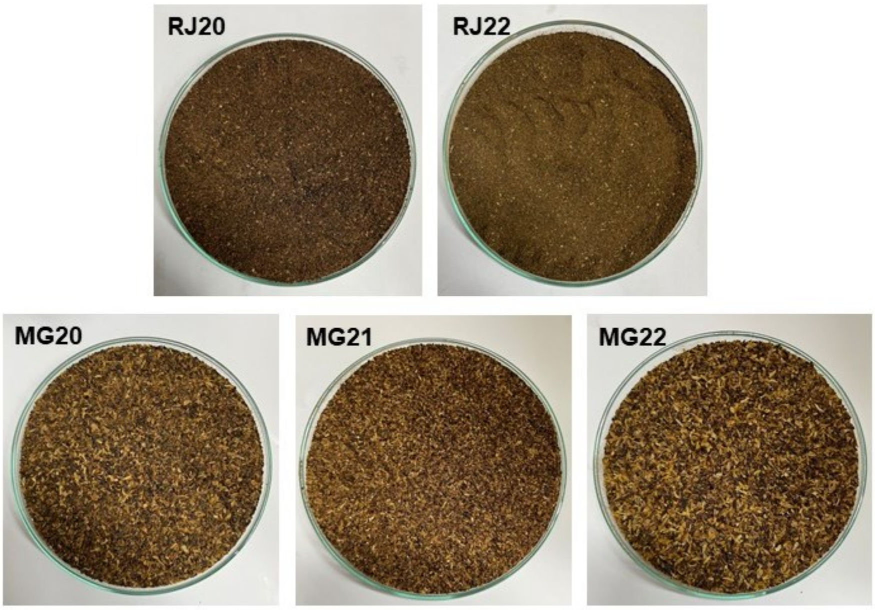
The CBB samples obtained and studied are shown in Figure 1. Colorimetric analysis determined the visible light reflection curve according to the CIELab scale.

The a* coordinate indicates the chroma measurement on the red-green axis (+a indicates red; –a indicates green). Positive values of a* were found for all analyzed samples, indicating proximity to the reddish color. However, samples RJ20 and RJ22, from the wet process, obtained lower a* indices value, suggesting that these samples have less red coloring than the others from dry process.

The b* index indicates the chroma measurement on the yellow-blue axis (+b indicates yellow; –b indicates blue). As in the previous index, positive b* values were observed for the samples, which resulted in proximity to yellowish coloration.

The Luminosity parameter obtained in the analyzed samples (79.11-79.29) can be considered high in relation to other coffee cascara matrices evaluated - for example, in the study by Cangussu et al.,[32] the luminosity index obtained was 44.93. The authors explain that low luminosity can be partially attributed to the degradation of anthocyanins by enzymatic action (peroxidases and polyphenoloxidases), which are released by damaged cells in the skin and pulp during handling and drying, or by other oxidizing agents, such as oxygen.[32]

Figure 1. CBB samples analyzed according to their origin.



RJ20: sample from RJ, wet processing, harvest 2020; RJ22: sample from RJ, wet processing, harvest 2022; MG20: sample from Machado – MG, dry processing, harvest 2020; MG21: sample from Machado – MG, dry processing, harvest 2021; MG22: sample from Nepomuceno – MG, dry processing, harvest 2022.

The results of the technological potential assessment of the CBB samples are presented in Table 3.

Table 3. Technological properties of CBB samples. São José do Vale do Rio Preto-RJ and Machado-MG, 2022.

Properties	Wet processing		Dry processing		
	RJ20	RJ22	MG20	MG21	MG22
[a]WA (g of water/g)	7.62[a]±0.04	7.56[a]±0.09	4.75[b]±0.13	4.86[b]±0.24	4.38[b]±0.27
[b]OA (g of oil/g)	2.46[a]±0.03	2.32[b]±0.04	2.36[b]±0.02	2.51[a]±0.02	2.55[ab]±0.16
[c]WS (%)	10.63[a]±0.04	20.29[b]±0.05	28.45[c]±0.01	30.88[cd]±0.09	33.27[d]±0.03
[d]SV (mL/g)	8.67[a]±0.15	12.78[b]±0.08	11.75[b]±0.09	12.47[b]±0.03	12.75[b]±0.06

Results are expressed as mean ± standard deviation.
Means with equal letters on the same line do not differ from each other by the Bonferroni correlation ($p \leq 0.05$).
[a]WA: water absorption index; [b]OA: oil absorption index; [c]WS: water solubility index; [d]SV: swelling volume.
RJ20: sample from RJ, wet processing, harvest 2020; RJ22: sample from RJ, wet processing, harvest 2022; MG20: sample from Machado – MG, dry processing, harvest 2020; MG21: sample from Machado – MG, dry processing, harvest 2021; MG22: sample from Nepomuceno – MG, dry processing, harvest 2022.

No significant differences were found between samples for WA from the same processing method, suggesting that the harvest did not interfere with this property. However, the type of processing to which the sample was subjected can impact WA. Samples from the wet process showed higher WA values than those from the dry processing, with a significant statistical difference. Cangussu et al.[32] evaluated only the WA of cascara and found similar values of 4.08 g of water/g. Comparing with other types of farinaceous products, Almeida et al.[33] obtained lower values when assessing the WA of feijoa husk flour (2.65 g of water/g), and Resende, Franca & Oliveira[34] obtained lower WA, 1.18 g water/g for buriti residue bran.

The WA of products is directly related to their chemical composition, since this property is mainly impacted by the content of carbohydrates, dietary fiber, and pectic substances.[33] Fibers play an important role in technological properties such as water retention, swelling, fat reducing agent during frying, bulking enhancer, binders, fat substitute and stabilizers in food industries.[17]

Samples RJ20 and RJ22 (wet processing) showed higher WA and higher total fiber content. Except for sample MG20, samples MG21 and MG22 (dry processing) showed lower values for these two parameters, respectively. Higher WA values are generally associated with soluble fibers, as they have greater hydration properties than insoluble fibers.[32] This fact may serve as a possible indication of the nature of the fibers in these samples. Physiologically, fiber hydration, promoted by water absorption from the matrix, can increase fecal volume and decrease intestinal transit time, which may help preventing colon cancer.[32]

The hydration capacity of plant cell wall material has been studied concerning the possible relationship with dietary fiber. They may partially determine the fate of fiber in the digestive tract (induction of fermentation) and are responsible for some of its physiological effects (increased fecal bulk by minimally fermented dietary fiber).[35]

Oil absorption (OA) is a technological property mainly related to the presence of hydrophobic groups in the food matrix.[9] According to the data obtained for the OA of the samples, a significant difference was found between samples from the same processing method. This suggests that, unlike water absorption, the harvest could impact on oil absorption. Cangussu et al.[32] evaluated cascara and found values higher than those in this study (5.21 g of oil/g). Borges et al.[36] observed similar results when analyzing açaí residue flour (2.47 g of oil/g), however, Leão et al.[37] obtained lower values when evaluating pequi residue bran (1.35 g of oil/g).

Proteins are characterized by having hydrophilic and hydrophobic functional groups. These hydrophobic groups can be physically and chemically associated with non-polar chains of the oil and promote its retention. Therefore, the quantity and quality of proteins present may be related to this factor.[32]

The OA property enhances the ability to emulsify and retain chemical compounds that can impart flavor to products.[32] Determining this index in by-products is relevant for developing new formulations involving cooking processes such as frying. It is important to understand this ability of by-products when they are added as a food ingredient, to determine if, and how, much they can retain fat and possibly preserve flavor during this type of preparation.[32,33]

WS is used to define the amount of water-soluble matter present in a given product.[34] Significant differences were found between samples from the same processing method as well as between different processing methods, suggesting that factors related to cultivation, harvesting conditions, and sample handling may interfere with this property.

Sample RJ20 showed the lowest WS compared to other percentages and was similar to the results found by Leão et al.[37] for pequi residue flour (epicarp + mesocarp) (16.7%). The RJ22 and MG20 samples obtained WS values close to those found by Resende, Franca & Oliveira[34] when studying buriti residue bran (endocarp) (23.61%). However, in the study developed by Silva et al.[38] when evaluating flours from fruit residues (husks), higher WS percentage (72.24%) was found compared to the values observed for coffee husk bran. Therefore, it is suggested that WS values are impacted by various factors, as evidenced in other parameters, but mainly in relation to the matrix being evaluated.

WA and WS have a close relationship with the moisture content of the raw material. A dehydrated product or one with a low moisture content may have a low water absorption capacity, and thus it will have a high capacity to solubilize in water, since WA and WS are inversely proportional parameters.[36] This statement corroborates the findings in this study, where, although all the evaluated samples have moisture content within the established by the Brazilian legislation for farinaceous and similar products, it is possible to verify that the wet processing samples (RJ) presented higher levels of WA and consequently obtained lower levels of WS; the opposite occurred with the dry process (MG) samples. The RJ20 sample had the lowest percentage of WS, sample that has the lowest amount of carbohydrates and the highest lipid content in its composition, which can impact the interaction with water.

The high solubility of an ingredient in water is an important property for preparations such as dextrinized mixtures, sauces, and soups, among others. Thus, products with higher WS values can be used in foods that require low preparation temperatures or ingredients with greater water solubility, such as bakery products, biscuits, and pasta.[36]

Swelling value (SV) is defined as the spontaneous fixation of water by the protein matrix and depends on the density, porosity and solubility of the material. This property is the first step that influences the solubilization of the polysaccharides present in the material and is related to the hydration properties of the product.[35]

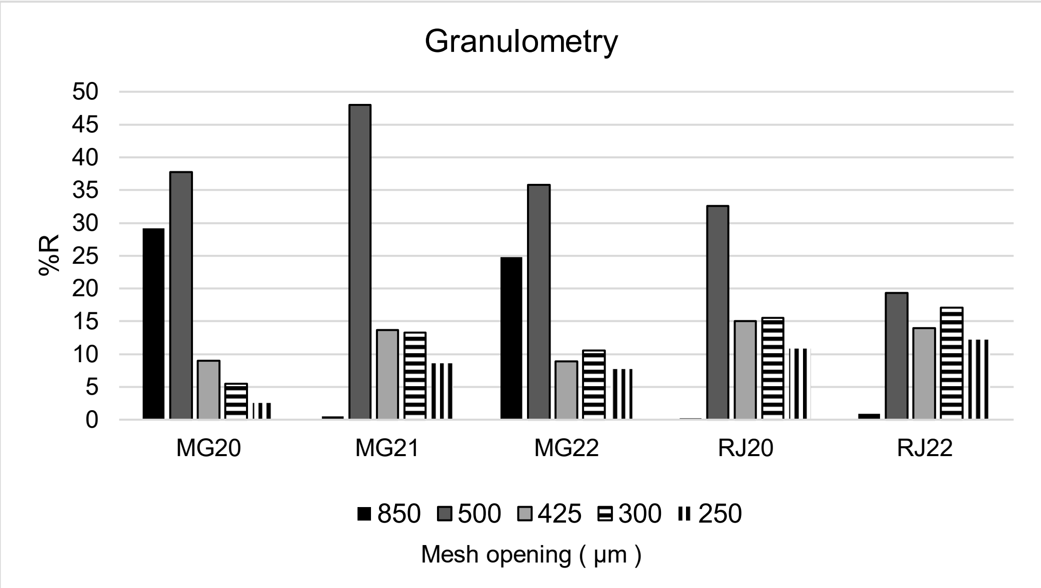
Regarding SV, only the RJ20 sample differed significantly from the others, suggesting that crop conditions may have impacted on this technological property of the sample. Cangusso et al.[32] obtained SV value of 8.75 mL/g, when studying husk of coffee, which is lower than that observed for the cascara (MG) analyzed in this study. Resende, Franca & Oliveira[34] found SV value of 11.36 mL/gfor buriti residue, which is close to the samples in this study.

Swelling is the ability of the material to expand and can influence the solubilization capacity. The CBB from the RJ20 crop had the lowest SV and the lowest solubilization capacity (WS). The other samples showed higher levels of swelling and consequently of solubility in water.

The SV of flours obtained from agricultural by-products is usually considered higher when compared to traditional wheat flour (4.75 mL/g).[39] Thus, it is suggested that flours obtained from by-products have a greater hydration capacity, and that the partial replacement of wheat flour by by-products flour can potentially positively impact the formulation of food products.

The results of the granulometric analysis are shown in Figure 2. This figure shows the relationship between the percentage of weight retained in each sieve and the size of the mesh opening for each analyzed sample.

Figure 2. Granulometric analysis results of the CBB calculated as % retention with different mesh openings (µm).



RJ20: sample from RJ, wet processing, harvest 2020; RJ22: sample from RJ, wet processing, harvest 2022; MG20: sample from Machado – MG, dry processing, harvest 2020; MG21: sample from Machado – MG, dry processing, harvest 2021; MG22: sample from Nepomuceno – MG, dry processing, harvest 2022.

Set of sieves, previously tared, with openings of 20, 32, 40, 48 and 60 mesh (850; 500; 425; 300 and 250 µm), respectively.

Raghavendra et al.[40] highlighted the influence of particle size on the water retention capacity of products. The authors tested different particle sizes of coconut fiber and observed an increase in hydration properties with the decrease in particle size, explained by the increase in total pore volume and surface area due to the rupture of the matrix structure and wall shear with grinding. However, the authors also observed a decrease in hydration properties with the reduction of particle size below 550 µm, suggesting possible damage to the fiber matrix and pore collapse due to grinding.

According to the results obtained from the particle size analysis of the CBB, it is possible to suggest that particle size may have impacted the hydration properties of the samples.[40] The wet processing samples (RJ20 and RJ22) have a higher percentage of weight retained in sieves with smaller openings, meaning they have smaller particles, and these samples also showed lower solubilization capacity, contrary to what was observed with the dry processing samples (MG20, MG21, and MG22), which have larger particles and consequently showed higher solubility indices.

It is important to analyze the particle size of brans because this parameter is related to technological properties and can directly impact the sensory characteristics of products, such as color and texture, and consequently, their potential use in food products.[32]

CONCLUSION

The results of the analyses performed on Arabica coffee by-products suggest that these brans have the potential for use by the food industry as a partial substitute for wheat flour to enrich food products, as they are a valuable source of dietary fiber. This helps increase daily fiber consumption, as recommended by health authorities. Additionally, these by-products can add value in terms of technological properties, improving the texture of products due to their absorption and solubility of water, which can contribute to the development of products such as bread, cakes, cookies, and pasta. Furthermore, coffee by-product brans can be considered a low-cost and sustainable food ingredient, as their utilization can help reduce the environmental impacts caused by improper disposal.

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Uekane, TM participated in conception of the study, analysis of results until the review of the final version of the article.Santos, BGparticipated in the stages from analysis performance and results, statistical analysis until writing and the review of the final version of the article. Oliveira, ISP;Rodrigues, MA; Martinez EC andPinto, ALC participated in the stages of the analysis performance and results.

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