CENTESIMAL, PHYSICO-CHEMICAL, BIOACTIVE AND MICROBIOLOGICAL CHARACTERIZATION OF PILSEN-TYPE MALT BAGASSE

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ABSTRACT

Objective: This study aimed to characterize malt bagasse obtained as the main residue from beer processing.

Theoretical benchmark: Malt bagasse is an agro-industrial waste with attractive nutritional characteristics, such as dietary fibers and proteins, intended for low or no added value purposes. In this sense, malt bagasse can nutritionally enrich various food products.

Method: The malt bagasse was dehydrated and then analyzed for its central characteristics (moisture, ash, proteins, dietary fiber, lipids, carbohydrates, energy value and mineral composition), physicochemical (pH, acidity and aw), bioactive (phenolic and antioxidant content) and microbiological.

Results and conclusion: As main results, malt bagasse showed high dietary fiber content (37.70 g/100 g) and high protein content (18.24 g/100 g), antioxidant capacity by the DPPH method with results expressed in EC50 as being 4.68 mg/mL and total phenolic content 360.99 mg EAG/100 g dry sample.

Implications of the research: The results of this study show a promising potential in the reuse of malt bagasse, to quote, in the incorporation into food for human consumption.

Keywords: Waste, Agro-Industry, Beer Production Chain.

CARACTERIZAÇÃO CENTESIMAL, FÍSICO-QUÍMICA, BIOATIVA E MICROBIOLÓGICA DO BAGAÇO DE MALTE TIPO PILSEN

RESUMO

Objetivo: Este estudo teve como objetivo caracterizar o bagaço de malte obtido como principal resíduo do processamento de cerveja.

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Referencial teórico: O bagaço de malte é um resíduo agroindustrial com características nutricionais atrativas, como por exemplo fibras alimentares e proteínas, destinado a finalidades com baixo ou nenhum valor agregado. Neste sentido, o bagaço de malte pode enriquecer nutricionalmente diversos produtos alimentícios.

Método: O bagaço de malte foi desidratado e em seguida foram analisadas às suas características centesimais (umidade, cinzas, proteínas, fibra alimentar, lipídios, carboidratos, valor energético e composição mineral), físico-químicas (pH, acidez e aw), bioativas (conteúdo fenólico e antioxidante) e microbiológicas.

Resultados e conclusão: Como resultados principais, o bagaço de malte apresentou alto teor de fibras alimentares (37,70 g/100 g) e alto teor de proteínas (18,24 g/100 g), capacidade antioxidante pelo método DPPH com resultados expressos em EC₅₀ como sendo de 4,68 mg/mL e conteúdo de fenólicos totais de 360,99 mg de EAG/100 g de amostra seca.

Implicações da pesquisa: Os resultados deste trabalho mostram um potencial promissor na reutilização do bagaço de malte, a citar, na incorporação em alimentos para consumo humano.

Palavras-chave: Resíduo, Agroindústria, Cadeia de Produção de Cerveja.

1 INTRODUCTION

With a growth of 11.6% compared to 2021, the Brazilian brewing sector, in the year 2022, presented 1729 breweries registered with the Ministry of Agriculture, Livestock and Supply (MAPA), with more than 85% of these located in the South-Southeast region. Santa Catarina ranked fourth in the list of states with the highest number of registered breweries (Associação Brasileira da Indústria da Cerveza, 2023; Ministério da Agricultura, Pecuária e Abastecimento, 2023).

The brewing process uses barley malt as one of the main ingredients, since it is it that provides the aroma and characteristic taste of beer (Portilho, 2010). Malted barley grains, after undergoing the brewing process, are called malt bagasse, and this represents about 85% of the total waste generated (Aliyu and Bala, 2011). It is basically malted barley husks and is the main waste from the brewing industry, being available all year round in large quantities and at low cost (Mussatto et al., 2006). It is estimated that for every 1000 L of beer produced, 350 kg of wet residue are obtained (Mello, 2014).

The main application of malt bagasse has been the destination for animal feed, or often for landfill, which presents itself as an alternative without economic return and which disregards environmental impacts (Robertson et al., 2010; Del Río et al., 2013). The environmental concern encourages the study of alternatives for the recovery of waste through its use for other purposes.

Various compounds of interest may be present in malt bagasse, such as fibers and proteins, and there are indications that malt bagasse is a source of bioactive compounds, since in barley's bark and cell wall it is where the majority of the phenolic compounds of the grains are found. In this sense, malt bagasse can be an option for nutritionally enriching food (Anjo, 2004; Oliveira and Marchini, 2008).

Thus, the present study aims to characterize malt bagasse, identifying characteristics that make this residue interesting for nobler and value-adding applications, and furthermore, offering alternatives for reducing environmental impacts.
2 THEORETICAL FRAME

2.1 Beer Production

The production of beer begins with the malting of the barley grain, a process that is carried out in three stages, being maceration, germination and drying (Venturini Filho, 2000). Barley is used in brewing because it has a high starch content, protein richness, grain uniformity and number of shells (Morado, 2009). There are several cultivated species, however, the barley used in maltarias is of varieties selected specifically for this purpose, and the one used for the production of beers is the one known as "brewing barley" (Ehrhardt and Sassen, 1995; Morado, 2009).

In general, beer can be defined as a carbonated beverage with an alcohol content of between 3 and 8% (v/v), prepared from malt of barley, hops, yeast and water, and the use of other raw materials such as rice, corn and wheat is allowed (Siqueira et al., 2009). According to Brazilian legislation, in Decree No. 9.902, of July 8, 2019, beer is the drink resulting from the fermentation, from brewing yeast, malted barley must or malt extract, previously submitted to a process of cooking added hops or hop extract, it being possible that a part of malted barley or malt extract is partially replaced by brewing adjunct (Brazil, 2019a).

The average consumption of beer per Brazilian is 67.9 liters per year, according to data from Kirin (Guia Da Beer, 2023) and the number of breweries registered in Brazil increases each year, with 85.9% located in the South and Southeast regions and that in the year 2022, presented 1729 breweries registered with the MAPA (Ministry of Agriculture, Livestock and Supply, 2023).

According to MAPA (2017), in 2016 Brazil manufactured 14.1 billion liters of beer, being the third largest producer, behind only China and the United States (Guía Da Beer, 2023). It is the third most popular drink worldwide after tea and coffee, and is the preferred alcoholic beverage (Rodhouse and Carbonero, 2017). Pilsen beer is still one of the best known and consumed styles worldwide (Fernandes and Franzen, 2011).

Generally speaking, industrial beer processing can be divided into 3 main steps, which comprise the essential operations:
1. Production of the must: composed of milling the malt; showing or enzymatic treatment of the must; filtration; boiling and treatment of the must (removal of the precipitate, cooling and aeration);
2. Fermentation process: involves fermentation and maturation;
3. Finishing: filtration, carbonation, clarification, modification of aroma and taste, standardization of color, pasteurization and bottling (Filho e Cereda, 2001; Almeida e Silva, 2005).

Filtration is the stage at which the extract must be separated from the mass. The solid part is called malt bagasse and the liquid part is the brewing wort (Bleier et al., 2013).

2.2 Brewing Industry Residue: Malt Bagasse

The industry generates a large amount of waste in its processes of processing and industrialization and Brazil stands out as a major generator of biomass waste, being estimated, in 2030, a growth projection to 1.402 million tons (Moraes et al., 2017). In this way, there is a growing concern with the environment, which encourages the study of alternatives for waste recovery through its use in various activities, since they can contribute positively to the minimization of environmental pollution, as well as lowering production costs and adding value to them (Brochier, 2007; Fernandes et al., 2008; Alexandre et al., 2013; Sylvio e Ferreira, 2021; Galvão et al., 2023). In this sense, the circular economy is highlighted, which aims to transform
waste into resources for the development of new products, minimizing the generation of waste and maximizing its use (Ferreira et al., 2017).

In the brewing process, the generation of large amounts of waste is confirmed, in which malt bagasse, denatured protein precipitated after boiling (trub) and yeast are produced as the main waste (Mussatto, 2014). From the evaluation of a brewing industry, it was observed that the amount of malt bagasse was 32.02% more than the amount of dry barley used as raw material, i.e. for each 100 kg of barley used was generated 132.02 kg of malt bagasse (due to its moisture) (Brochier and Carvalho, 2009).

Malt bagasse accounts for approximately 85% of the total waste generated in the brewing process, and is thus the most important (Aliyu and Bala, 2011). Furthermore, there is a great supply of this waste throughout the year, which makes it feasible to use it in research (Geron, 2006).

Studies highlight that solid waste such as malt bagasse after processing can be sold to local farmers, generating financial returns, as it is an important source of nutrients (Fakoya and Van Der Poll, 2013; Mussatto et al., 2006; Pauli, 2010; Rosa and Beloborodko, 2015).

Many studies show the use of malt bagasse for animal feed, to examples for the feeding of broilers (Parpinelli, 2016; Filho, 2017; Assunção et al., 2018), pigs (Albuquerque et al., 2011; Verde et al., 2019), cattle (Geron et al., 2008; Stefanello, 2017), goats (Silva et al., 2010) and lambs (Brochier and Carvalho, 2009; Gilaverte et al., 2011; Carvalho et al., 2016). It is worth highlighting that for use in animal feed one must take care of the possibility of disturbances in animals, such as ruminal acidosis, laminitis, botulism and poisonings by Aspergillus clavatus and ethanol, resulting mainly from inadequate storage (Brust et al., 2015).

Studies described in the literature report possibilities for using malt bagasse in several areas, including: for energy generation, from fermentation by microorganisms (Mello, 2014), for biofuel production, through pyrolysis (Borel et al., 2018; Luft et al., 2019); as a source of nitrogen for fertilizer formulation (Mello, 2014), in food packaging production (Ferreira et al., 2019), as a substrate for growing crops edible insects (Mancini et al., 2019), bioethanol production (Lima et al., 2014), ecological brick development (Menezes and Yamashita, 2017) and activated carbon production (Sahu et al., 2010).

Due to the high moisture content of malt bagasse, it is the main limiting factor in its use. Transport over long distances is economically unviable, since the use of bagasse for animal feed, for example, depends on proper conservation (Pedroso e Carvalho, 2006).

In general, malt bagasse is rich in protein, fiber and ash, with a medium carbohydrate content and low in lipids. In addition, it is considered a source of bioactive compounds, such as phenolic acids, because in barley bark and cell wall it is where most of the phenolic compounds and hydroxycinnamic acids of barley grains are found (Almeida, 2014).

According to its nutritional composition, its use in human food is a good alternative for the improvement and enrichment of products (Tombini et al., 2020a). Several authors have studied the incorporation of malt bagasse into baked products, such as the production of malt bagasse flour with partial replacement of wheat flour (Panzarini et al., 2014) or as baked dough in the form of toothpicks or as bread (Mattos, 2010; Ktenioudaki et al., 2012; Teixeira et al., 2018; Tombini et al., 2020b) and the application of this to the production of cookies type of cookies (Vargas et al., 2021).

The total reuse of this waste is not only interesting from an economic and nutritional point of view, but also from an environmental point of view, since it contributes to the solution of pollution problems (Mussatto et al., 2008).
3 METHODOLOGY

3.1 Preparation of Malt Bagasse

The malt bagasse used for the study was donated by Dalla Cervejaria, located in the west of Santa Catarina - Brazil, from the production of beer type pilsen, being stored frozen in vertical freezer (brand Electrolux, model FE22) at -18 °C until the analyzes were carried out. Malt bagasse has undergone a drying process in a drying oven (Macanuda brand, model DMS-P) at 60 °C to constant weight, this value determined through studies that indicate that higher temperatures can cause changes in the structure of the grains, compromising the quality of the product (Khan et al., 2009; Mello et al., 2013; Almeida, 2014; Mathias et al., 2014; Melo et al., 2016; Bagatini et al., 2018) (2).

3.2 Characterization of Malt Bagasse

Centesimal characterization: The centesimal characterization of malt bagasse consisted of analyzes of moisture and ash according to the methodologies proposed by the Adolfo Lutz Institute (2008), carried out in triplicate. For the determination of the protein content, the methodology described by ISO 1871:2009 was followed by multiplying the total nitrogen content of the sample by the factor 6.25, carried out in triplicate. The analysis of lipids followed the analytical march proposed by the Goldfish TE-044-5/50 (Tecnal brand) fat-determining equipment (triplicate). The dietary fiber was determined following the methodology described by the Association of Official Analytical Chemists (AOAC), method No. 985.29 (AOAC, 2005) and American Association of Cereal Chemists (AACC), method No. 32-05.01 (AACC, 1991), using the Megazyme Total Dietary Fiber kit (duplicate). The carbohydrate content was determined by calculation taking into account the averages obtained in the analyzes of proteins, lipids, ashes and humidity, as recommended by Normative Instruction No. 75 (2020), adapted on the basis of the methodology proposed by INFOODS - International Network of Food Data Systems, FAO - Food and Agriculture Organization (Brazil, 2020; Maclean et al., 2003). The energy value of malt bagasse was determined on the basis of IN No. 75/2020, using conversion factors of 4 kcal/g for carbohydrates and proteins and 9 kcal/g for lipids, expressed in kcal/100 g (Brazil, 2020). The results obtained from the analyzes of centesimal composition were expressed on dry and wet basis.

The mineral composition was determined by outsourced laboratory (3rlab) using an inductively coupled plasma optical emission spectrometer (ICP-OES), model ICP 8300 (brand Perkin Elmer), with only one repetition.

The physicochemical analyzes of pH and acidity followed the methodologies proposed by the Adolfo Lutz Institute (2008), carried out in triplicate. The determination of water activity followed the methodology ABNT NBR ISO 18787:2019, employing equipment Novasina Modelo Lab Touch Aw, being carried out in a third party laboratory for food analysis (SENAI - Brasil), with only one repetition.

The extraction for the determination of the total phenolic compounds and for the determination of the antioxidant potential was carried out following the methodology proposed by Meneses (2013), using as solvent acetone and water (60:40). The total phenolic compounds present in the samples were determined by the colorimetric method Folin-Ciocalteau, with modifications (Bonoli, 2004). Quantitative evaluation of antioxidant activity was determined using the methodology based on the ability of the extract to sequester 1,1-diphenyl-2-picrylhydrazyl radicals (DPPH method), with small modifications and results expressed in EC50 (Brand-Williams; Cuvelier; Berset, 1995). Both determinations were carried out in triplicate.
The microbiological analysis was carried out on the basis of the parameters established by CPR No. 331 of December 23, 2019, from the National Health Surveillance Agency - ANVISA, for Salmonella ssp., Escherichia coli and molds and yeasts (Brazil, 2019c), with only one repetition. AOAC OMA 997.02 methodology for analysis of molds and yeasts followed (AOAC, 2019a). For Salmonella ssp. analysis, the methodology NF EN ISO 6579-1/A1 (AFNOR, 2020), and for Escherichia coli, the methodology AOAC OMA 998.08 (AOAC, 2019b).

4 RESULTS AND DISCUSSION

4.1 Characterization of Malt Bagasse

Table 1 presents the results of the analyzes of the centesimal composition of malt bagasse expressed on wet and dry basis.

Table 1 - Centesimal composition of malt bagasse (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Component</th>
<th>Wet base</th>
<th>Dry base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity (g/100 g)</td>
<td>78.92 ± 0.57</td>
<td>-</td>
</tr>
<tr>
<td>Ash (g/100 g)</td>
<td>0.65 ± 0.01</td>
<td>3.09 ± 0.03</td>
</tr>
<tr>
<td>Crude protein (g/100 g)</td>
<td>3.85 ± 0.01</td>
<td>18.24 ± 0.09</td>
</tr>
<tr>
<td>Lipids (g/100 g)</td>
<td>0.01 ± 0.01</td>
<td>4.40 ± 0.49</td>
</tr>
<tr>
<td>Dietary fiber (g/100 g)</td>
<td>7.83 ± 0.17</td>
<td>37.70 ± 0.28</td>
</tr>
<tr>
<td>Carbohydrates (g/100 g)</td>
<td>16.56</td>
<td>74.27</td>
</tr>
<tr>
<td>Energy value (kcal/100 g)</td>
<td>81.70</td>
<td>397.85</td>
</tr>
</tbody>
</table>

Source: drafted by the authors.

Malt bagasse leaves the beer production process with a high degree of humidity, since it is removed from the filtration of the must, where the mixture is composed only of malted barley grain and water, and the humidity of the bagasse was 78.92%. In the studies of Cordeiro, El-Aouar and Gusmão (2012) the humidity was 75.45% for malt bagasse pilsen and adjuncts, for Mathias, Mello and Servulo (2014) it was 82.60 ± 0.10% for malt bagasse pilsen and for Onofre et al. (2018) it was 78.23 ± 1.45% for malt bagasse pilsen and adjuncts. The high moisture content present in this waste can be a limiting factor of its use, which makes it highly susceptible to microbiological contamination (Linhares, 2018).

The ash content obtained for malt bagasse was 3.09 ± 0.03 %. This value is generally small and is consistent with the data found in the literature as Khidzir et al. (2010), in which the result was 2.30 ± 0.80%, for Mathias, Mello and Servulo (2014), which was 3.85 ± 0.00%, for Onofre et al. (2018), which was 3.76 ± 1.23% and for Almeida et al. (2017) which was 3.23 ± 0%, contradicting the value obtained by Cordeiro, El-Aouar and Gusmão (2012) which was 0.74%. This difference can be explained by the quality and origin of the grains used, as well as the possible use of adjuncts.

Furthermore, as the ash content refers to the content of fixed mineral waste, related to the presence of mineral compounds such as magnesium, iron, sodium, potassium, among others, after the burning of organic matter (Zambiazi, 2010), this value is an indication of the content of minerals present in the malt bagasse.

Protein is an extremely important component of food, both for nutrition, due to the supply of amino acids, and for cell function. In the crude protein analysis, 3.89% of the total composition of the analyzed residue was obtained on a wet basis. The value found in this study was lower than the values reported by Cordeiro (2011), who obtained 5.37% crude protein and Onofre et al. (2018), with 4.89% of this constituent for the analysis of malt pilsen and adjuncts, both on a wet basis. Souza et al. (2020) found a value of 11.68% crude protein in whole barley...
malt, on a dry basis, lower result than that obtained in this study (18.24 g/100 g). Jacometti et al. (2015), in turn, also presented protein content for malt bagasse as being lower than that obtained in this study, of 13.60 ± 0.90 g/100 g, on dry basis. Almeida et al. (2017) found a value for protein content in malt pilsen bagasse very similar, being this 18.5%.

Assessing the protein content, malt bagasse can be considered as high protein content, as it has protein content higher than 20% of the VDR. for proteins, as established in Brazilian legislation IN nº. 75/2020 (Brazil, 2020).

The analysis of the lipid content present in malt bagasse showed that this residue has 4.40% of this constituent, on dry basis, a value very close to that found by Jacometti et al. (2015), which presented 4.44 ± 0.14 g/100 g of lipids. For Onofre et al. (2018), the percentage of lipids obtained for malt pilsen bagasse and adjuncts was 2.67%. The study proposed by Almeida et al. (2017) obtained a percentage of lipids of 6.42% for malt pilsen bagasse. A reduced lipid value is desirable, because high levels can increase calorie value when incorporated into food, in addition to undergoing oxidation, and can alter sensory attributes (Rigo et al., 2017).

The dietary fiber content of the malt bagasse classifies it as high fiber content according to IN No. 75/2020 (Brazil, 2020), since its value - 37.70 g/100 g on dry basis and 7.83 g/100 g on dry basis - was higher than 25% of the VDR. for dietary fiber (which corresponds to the minimum of 5 g). Compared to the value presented by the study by Onofre et al. (2018), in which the authors found the value of 4.19 g/100 g (wet basis), the value obtained for the malt bagasse of this study proved superior. Fujita and Figueroa (2003) carried out a study in which they obtained values of dietary fiber, on a wet basis, from oats in flakes, with values that varied from 13.86 to 16.93%.

In relation to the carbohydrate content obtained by the difference, the method of which is widely disseminated and established in the literature (Gotthardi et al., 2018; Instituto Adolfo Lutz, 2008; Melo et al., 2016; Rigo et al., 2017), malt bagasse showed 74.27 g/100 g of this constituent. This value is very similar to that presented by Jacometti et al. (2015), of 73.84 g/100 g. It should be noted that the dietary fiber content contributes to this result, and by discounting the dietary fiber content of carbohydrates, a value for this constituent is obtained as being 36.57 g/100 g on dry basis. On a wet basis, the value obtained in this study was 8.74 g/100 g, which was close to that obtained by Cordeiro (2011), which was 15.46 g/100 g. Brazilian malt has a carbohydrate content of around 76% (Aquarone et al., 2001), which indicates that high levels of carbohydrates in malt bagasse are consistent, even with the transfer of a good part of these sugars and starches to the stages of beer production (Ceccato, 2019). Malt bagasse can generally be considered a good source of carbohydrates (Cordeiro, 2011).

As for the energy value (397.85 and 81.70 kcal/100 g on dry and wet basis, respectively), this is similar to the value presented by Cordeiro (2011), which indicated the energy content as being 105.19 kcal/100 g on wet basis and Onofre et al. (2018), with 109.23 kcal/100 g. When comparing the energy value obtained for malt bagasse with barley malt, it can be seen that they are very close, as the latter has a value of around 395 kcal/100 g, on dry basis (Souza, 2020).

The analysis of minerals performed presented the composition expressed in Table 2, on dry basis.
Table 2 - Mineral composition of malt bagasse

<table>
<thead>
<tr>
<th>Mineral</th>
<th>g/100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>0.1100</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.3400</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.1200</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.1800</td>
</tr>
<tr>
<td>Sodium</td>
<td>NA*</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.1500</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.0082</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.0037</td>
</tr>
<tr>
<td>Copper</td>
<td>0.0016</td>
</tr>
<tr>
<td>Iron</td>
<td>0.0194</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.1287</td>
</tr>
<tr>
<td>Boron</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

*Not detected.

Source: drafted by the authors.

It is observed that the mineral present in greatest quantity is phosphorus, followed by potassium. Minerals exercise a controlling function in the human organism, being fundamental for its proper functioning, such as the regulation of enzymatic activities and the absorption of essential nutrients (Zancul, 2004; Granato et al., 2009).

Although phosphorus is the mineral present in greatest quantity in the malt bagasse analyzed, this value is lower than that found by Almeida (2014) and Meneses et al. (2013), in which the malt bagasse analyzed in these studies showed 0.6000 and 0.4883 g/100 g, respectively.

The calcium and magnesium content observed in malt bagasse is particularly higher than those commonly found in other cereals, such as rice type 1 (0.004 and 0.03 g/100 g, respectively) and oats (0.048 and 0.119 g/100 g, respectively) (NEPA, 2011).

Table 3 presents the physico-chemical parameters of acidity, pH and water activity (Aw) for malt bagasse, on a dry basis.

Table 3 - Physical-chemical parameters of malt bagasse (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidity (%)</td>
<td>5.08 ± 0.34</td>
</tr>
<tr>
<td>pH</td>
<td>4.36 ± 0.06</td>
</tr>
<tr>
<td>Aw</td>
<td>&lt;0.328</td>
</tr>
</tbody>
</table>

Source: drafted by the authors.

The determined acidity for malt bagasse was 5.08 ± 0.34 %. According to literature data, the main constituent acids of malt bagasse are amino acids and phenolic acids, which give this residue an antioxidant potential, and acetic acid (Palmqvist and Hahn-Hägerdal, 2000; Mussatto et al., 2006; Xiros and Christakopoulos, 2012; Mussatto, 2014; Lynch et al., 2016). Almeida (2014) found 8.03% of acidity in malt bagasse, a value higher than that found in this study.

The malt cake used for the study development was slightly acidic, with a pH of 4.36 ± 0.06, slightly lower than the values found in the literature. Rêgo and Brito (2021), used in their study, malt bagasse flour, with pH equal to 5.11 ± 0.03. The study by Melo et al. (2016) also shows a pH of 5.86 ± 0.04 for malt bagasse flour. Mello, Vergílio and Mali (2013) found a value of 5.73 for the pH of pilsen-type malt bagasse, and Almeida et al. (2017), the value of 5.93 ± 0.05, also for pilsen beer residue. Furthermore, it should be pointed out that the treatment of beer water may have been different, which explains the variation in values.

In relation to the water activity of the malt bagasse used, it is observed that this value is less than 0.328 (limit of detection of the equipment), which contributes to its microbiological
stability, since for any type of microorganism, the minimum value of Aw required for growth is 0.60 (Jay, 2005).

The composition of food of plant origin generally depends on factors such as variety, place and year of production, soil composition and time of harvest, climatic conditions, among other factors (Shahidi and Miraliakbari, 2005; Villarreal-Lozoya et al., 2007). In addition, malting of barley grain and the process of showing may also imply variations and explain the differences observed in the present study and in the values reported in the literature (Santos et al., 2003; Almeida et al., 2017; Rigo et al., 2017; Gotthardi et al., 2018).

Table 4 presents the results obtained for the total phenolic content and the antioxidant capacity of malt bagasse.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Malt meal, dehydrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phenolic content (mg SAE/100 g sample)</td>
<td>360.99 ± 4.68</td>
</tr>
<tr>
<td>Antioxidant capacity DPPH - EC\text{50} (mg/mL)</td>
<td>4.68 ± 0.95</td>
</tr>
</tbody>
</table>

EAG = gallic acid equivalent.

Source: drafted by the authors.

Almeida et al. (2017), found values for the total phenolic content of malt pilsen bagasse as being 380.28 ± 59.99 mg of EAG/100 g of sample, using ethanol and water (20:80) as solvent, this value similar to that found in this study (360.99 mg of EAG/100 g of sample). Meneses et al. (2013) found the value of 9.9 mg EAG/g of sample, using acetone and water (60:40) as solvent. The difference observed may be due to the extraction method, in addition to the variations of the barley malt itself, whose type was not identified in the study, as well as, by the conditions of the beer production process.

According to Kähkönen et al. (1999) the content of total phenolic compounds in cereals can generally vary between 20-130 mg of EAG/100 g. These authors found 400 mg of SAE/100 g of barley grain, which is more than most other cereals. Thus, it can be inferred that even after the brewing process, a significant amount of phenolic compounds still remain in the residue of the process, demonstrating the importance of the recovery of this process for human consumption.

Regarding the antioxidant analysis, it should be noted that the EC50 value is inversely correlated with the anti-radical activity and when the EC50 value is low, it means that the abdution of the DPPH radical by the sample is high and thus, its antioxidant capacity is high. The results are expressed as the amount of antioxidant needed to decrease the initial DPPH concentration (EC50) by 50% at a fixed reaction time, or until the formation of a plateau (Brand-Williams et al., 1995). Therefore, the malt bagasse sample showed antioxidant capacity for the DPPH assay as 4.68 ± 0.95 mg/mL. Almeida et al. (2017) obtained a similar result for malt bagasse, being 6.63 ± 0.09 mg/mL, and can potentially be considered a source of bioactive compounds, according to the author. Almeida (2014) evidenced in his study that the method that obtained the best response in the antioxidant analysis among the tested, was the DPPH - EC50.

It is noted that there is no official method for determining antioxidant activity in foods of plant origin and their by-products, considering the diversity of antioxidant mechanisms that can occur, as well as the varied bioactive compounds (Sousa et al., 2011).

### 4.2 Microbiological Characterization of Malt Bagasse

Table 5 presents the results obtained from microbiological analyzes performed for malt bagasse.
It can be observed that, from a microbiological point of view, malt bagasse can be classified as satisfactory with acceptable quality, in accordance with Normative Instruction No. 60 (Brazil, 2019b), where the analytical results are lower than the minimum number (m) established by legislation.

Microbiological evaluation is all the more necessary where, as in this case, the pH of malt bagasse has been found to be slightly acidic to demonstrate the acceptable quality of the waste in return for its reuse.

5 FINAL CONSIDERATIONS

Malt bagasse is a waste that has a high potential for reuse, namely, when incorporated into foodstuffs for human consumption, because it has a high nutritional value that characterizes it as having a high content of fiber and proteins, with 37.7 g/100 g and 18.24 g/100 g of these constituents, respectively. In addition, from the point of view of bioactive compounds, malt bagasse showed interesting values of total phenolic compounds (360.99 mg EAG/100 g) and antioxidant capacity (4.68 mg/mL). The characterization of the malt bagasse indicated that, with the correct handling, although it has high levels of humidity (78.92%), this residue has an acceptable microbiological quality and can be used, for example, in the development of food.

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REFERENCES


