Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Systematic analysis on the incorporation of malt waste in different production processes aiming for cleaner production.

Eduarda Bertoletti Duarte
Bióloga, Mestranda em Tecnologias Limpas
eduardabertoletti@gmail.com

Luciana Cristina Soto Herek Rezende
Orientadora, Doutora, Mestrado em Tecnologias Limpas, UNICESUMAR. Pesquisadora do Instituto Cesumar de Ciência, Tecnologia e Inovação – ICETI
luciana.rezende@unicesumar.edu.br

Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

RESUMO

During the production of the beverage, in addition to the high amount of water used in the process, there is also the generation of waste, especially malt bagasse, generating 20 kg of waste per one hundred liters of beer. A systematic analysis was conducted on the insertion of this bagasse in new production cycles. Descriptors in Portuguese and English were used in the WEB OF SCIENCES, SciELO, CAPES Periodical, SCOPUS and BDTD databases, from 2000 to December/2021. The most prominent research was those that evaluated the composition of bagasse, followed by the insertion of the residue in human food and its use for energy generation. It was possible to verify, through this research, the potential of bagasse in different production processes, in addition to its versatility and attractive chemical composition. Despite the data presented demonstrating the efficiency of the residue, studies are still scarce, and continuous research is necessary for the improvement of processes.

PALAVRAS-CHAVE: Brewing industry. Organic matter. Source reduction.

1. INTRODUCTION

The balance between economic development and environmental protection is the main objective of sustainability focused studies, where one of the adopted strategies is a cleaner production (CP), an important tool of the Environmental Management System (EMS) (OLIVEIRA et al., 2009).

Regardless of a cleaner production process, its goal is to reduce pollution at the source, which is one of the objectives of the 2030 Agenda, an action plan that sets 17 sustainable development goals and, within them, 169 targets to end hunger, fight climate change and obtain environmental protection, aiming to reduce the environmental impact, use water consciously, and reduce and reuse residue (ONU, 2016).

Goal 12 has as a main theme the search for more responsible consumption and production, featuring targets that aim at the use of natural resources, food waste, management and reduction of waste, public education, monitoring of the fulfillment and minimization of the impact of overconsumption of fossil fuels (ONU, 2016). Inside of SDG 12, we stress goals 12.2, that aim for the management and efficient use of resources; 12.4, that aim at handling of waste in its entire cycle of life, including the reduction of dumping practices and their impacts; and 12.5, that encourages the prevention, reduction, recycling and reuse for waste reduction.

Regarding waste, the food industry is responsible for a significant generation of it, which is a result of many different processes (NASCIMENTO FILHO; FRANCO, 2015). It is estimated that, in many phases, there are significant losses that culminate in the generation of residues, with composition varying according to the nature of the product and the techniques used in its processes, resulting in loss of raw materials and energy (NASCIMENTO FILHO; FRANCO, 2015).

Inside of the food industry, the highlight is in the beer industry, with Brazil being considered the third biggest manufacturer in the world, with a production close to 14 million litters, only behind China and the United States (KIRIN GLOBAL BEER REPORT, 2019). According to the Ministry of Agriculture, Livestock and Supply (MAPA) (2019), the beermaking sector represents around 2% of the GPD, earning R$100 billion/year.

During the brewing of the beverage, there is a significant generation of waste. Among the main solids, we highlight malt bagasse, used yeast, and muck from the treatment station,

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

the first being used in bigger quantities, constituting more than 80% of the subproducts (TOMBINI et al., 2012).

Malt is the product of the germination of any cereal seeds under controlled conditions in the malting process, barley being a part of the Hordeum grasses family, the most common cereal for production (PORTO, 2011).

The bagasse is a subproduct generated after the mashing and depletion of the ground malt grains. Throughout these processing steps, the solids get separated, forming the malt bagasse, and the liquid carries on to the brewing process (MATHIAS et al., 2015).

It is considered a promising material to be reintroduced in new processes, since it is generated in large scale annually. Besides the low cost of it being added to new techniques, its composition varies due to the different kinds of malt, recipes and processes in which it is used (MUSSATTO, 2014). A 100 liter brew of beer generates around 20 kilos of malt bagasse, with humidity varying from 70 to 80%. Considering an annual proportion, in 2016 the result would have been 2,82 million tons of generated waste (MUSSATTO, 2014).

2. OBJECTIVES

Therefore, waste management leads to more studies and technologies to reintroduce these residues to other processes. This article had as an objective making a systematic analysis of the insertion of malt waste in different production processes, searching for studies that aim to lessen the disposal of a product that can still be incorporated in other productive chains, aiming for cleaner production as a way to minimize environmental impact.

3. METHODOLOGY

The starting point of the quali-quantitative analysis was a systematic review, in an ample and discriminating way, on the incorporation of waste in different processes applied to a cleaner production. The consulted databases were Web of Sciences (WOS), SciELO – Scientific Electronic Library Online, Periódicos CAPES, SCOPUS e BDTD.

The descriptors used were "Bagaço Malte", "Gestão de Resíduos AND cervejaria", "Produção Mais Limpa AND cerveja", "Resíduo cervejaria", "Resíduo Malte", "Compósito AND malte", "Construção AND malte", "Fibra de reforço AND malte", "Spent Grain AND residue/waste", "Brewery AND residue/waste", "Malt AND byproducts", "Malt AND biopolymer".

As article selection criteria, publication date (from 2000 to 2021), the descriptors and the adherence of the articles to the objectives of this study were considered. Academic works that hadn't been in conformity with such criteria were not used as bibliography.

After gathering, these academic works were perused and discarded based on the selection criteria, allowing to funnel the research more specifically. The articles that reached the criteria of this research were analyzed and evaluated, read fully and tabled in an Excel ® Version 10 spreadsheet, which allowed categorizing the themes of the articles as either Human Feeding, Environmental, Evaluation, Cosmetics, Energy, New Products or Substrate. After that division, it was possible to analyze the data and construct the article.

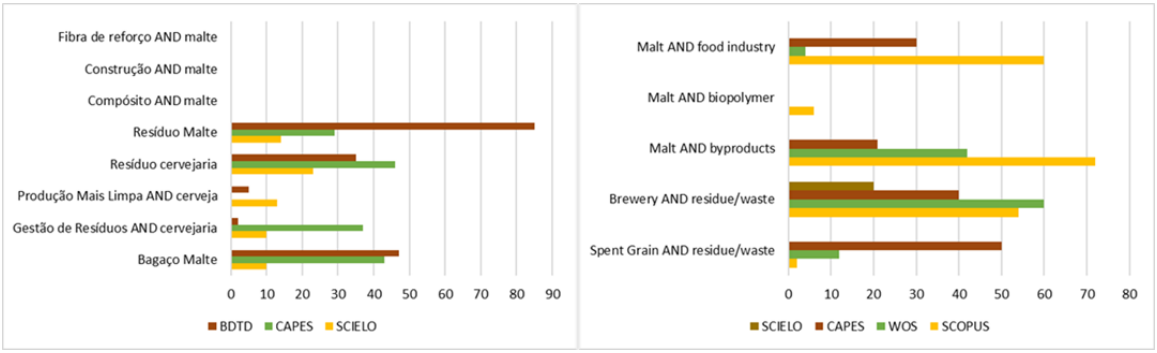
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

4. RESULTS

After searching for the articles that fit the researched theme, works that didn't comply with the objectives of this study and didn't satisfy the determined chronology (2000 to 2021) were excluded. At the end, 163 articles were obtained.

Regarding bibliographical search, in Image 1, one can observe which descriptors were more effective. In the Portuguese, Image 1 (a), "Resíduo Malte", "Resíduo Cervejaria" and "Bagaço Malte" were the descriptors that allowed for the biggest access to articles (over 20 articles) observing the three databases. "Gestão de Resíduos AND cervejaria" led to a satisfactory result at the CAPES database.

Figure 1 – List of descriptors by database (a) in Portuguese and (b) in English



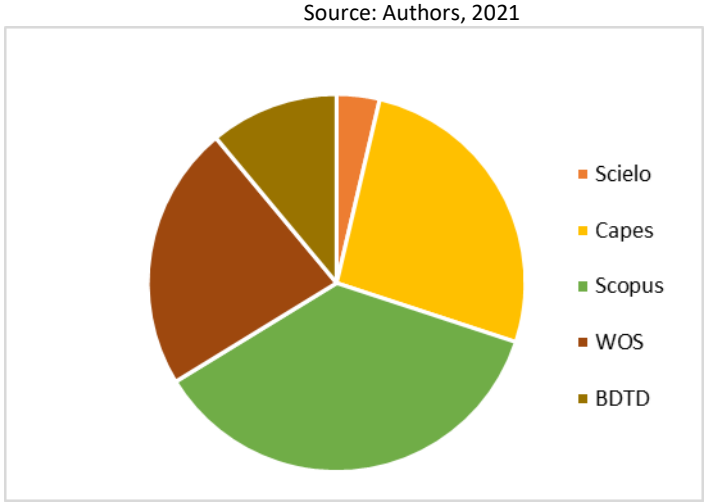
Source: Authors, 2021

By observing the English descriptors in Image 1 (b), only "Malt AND biopolymer" was less adherent, with less than 20 articles, when compared to the other descriptors. "Brewery AND residue/waste" and "Malt AND byproducts" were better performing descriptors, with over 100 articles when observing the three databases together.

The articles were divided by the database they were found at and in Image 2 it is possible to observe that Scopus and Capes were, respectively, the databases that allowed for the biggest selection of articles, since they resulted in the biggest number of articles with adherence to the theme of this study. SciELO, on the other hand, allowed a significantly smaller selection. Most of the articles found in this database had a focus on animal feeding, which wasn't included in this project.

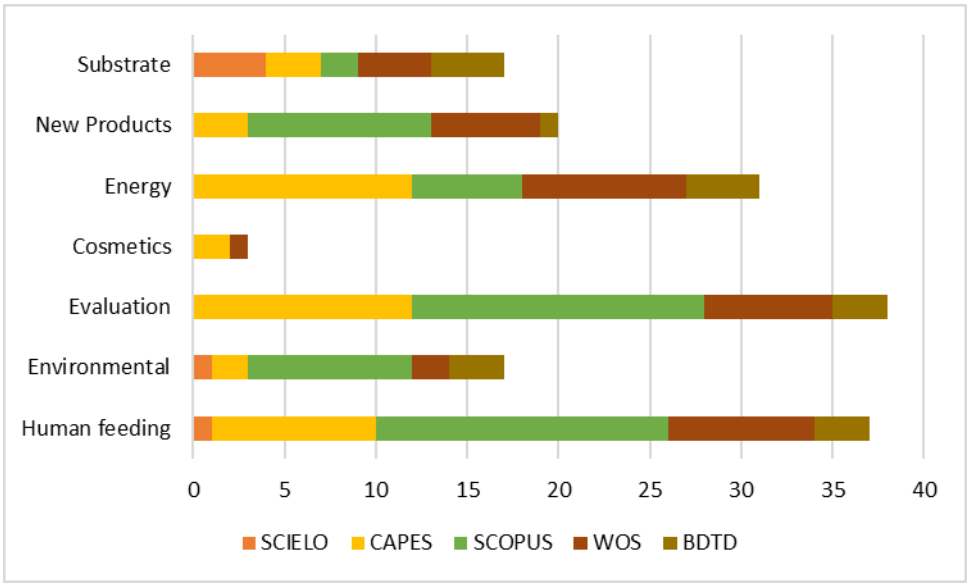
ISSN 1980-0827 – Volume 19, Number 5, Year 2023

Figure 2 – List of articles by database.
Source: Authors, 2021



The articles included in the study were read and then classified according to the focus of each one, being put into the categories proposed by the authors. Image 3 shows the distribution of article categories in each database.

Figure 1- Quantity of articles found by are in each database.



Source: Authors, 2021

The Evaluation category was frequent at Capes, Scopus and Web of Science (WoS) databases. Capes, Scopus and BDTD showed a high frequency of the Human Feeding category, while the Energy category was more frequently found in the Capes and WoS databases. The categories Cosmetics and Environmental presented less frequently among all three databases. That shows the investment in studies for the insertion of residues in feeding and energy, by being areas inherent to human development, like the search for more natural and sustainable eating and new sources of biofuels.

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

4.1. Results by researched categories

4.1.1. Evaluation

The Evaluation category regards the analysis of properties, composition, characteristics, potential uses and presence of specific molecules of/in the malt bagasse. Inside the aforementioned selection, 38 articles were found. Brewer's spent grain (BSG) is the grain residue that results from it going through the malting and maceration process (JAEGER et al., 2021). It is composed mainly of malt husk pericarp and seed integument, making it rich in cellulosic polysaccharides, especially lignin, cellulose, and hemicellulose (DEL RIO; PRINSEN; GUTIÉRREZ, 2013; JAEGER et al., 2021). With this composition, this residue is considered a good source of fibrous material, since polysaccharides are resistant to hydrolysis by the digestive enzymes of the small intestines (DEL RIO; PRINSEN; GUTIÉRREZ, 2013).

Aside from that, the residue is rich in carbohydrates, proteins, lipids, and vitamins (JAEGER et al., 2021; LORDAN et al., 2019; MATHIAS et al., 2015; DEL RIO; PRINSEN; GUTIÉRREZ, 2013). The concentration of these molecules in the spent grain varies due to factors like the type of cereal used, addition of adjuvants, mashing phase conditions, mashing and clarifying (MATHIAS et al., 2015).

Del Río et al. (2017) did an evaluation of the composition of the main constituents of BSG and identify that the lipids represented over 9% of the dry material, triglycerides predominating, followed by free fatty acids and steroid compounds. It is possible to observe the presence of antioxidant activity from the phenolic compounds in the malt bagasse, making it possible to categorize it as a source of bioactive antioxidant compounds (ALMEIDA et al., 2017).

4.1.2. Human feeding

The Human Feeding category was composed of 37 articles with this focus. As previously mentioned, malt waste is composed by components of big nutritional potential. The studies in this area have made it possible to include these residues in *snacks,* baking products such as breads and cakes and other foods in lesser frequency. In relation to snack focused research, such as chips, the frequency of studies was bigger.

The amount of BSG inserted varied between the articles. A difficulty in relation to the weak expansion in which the waste is inserted was relayed, but this problem was resolved by the insertion of pectin (JOZINOVIĆ et al., 2021; AČKAR et al., 2018). The extrusion technique of snacks with subproducts was the most used, as observed in Jozinović *et al*. (2021), Grasso (2020), Ačkar et al. (2018); Bieli (2015), Kirjoranta, Tenkanen and Jouppila (2016). This tecnicque was more efficient because it allowed for a reduction in time and cost, a smaller physical space and bigger flexibility for the production of different byproduct, by only changing the matrix, the process conditions and the granulometrics of the raw materials (OLIVEIRA et al., 2013).

Beyond the benefits of fiber inclusion, the audition raises the nutritional value of the snacks, because it significantly betters the food fiber levels and brute proteins (BIELI, 2015). However, a difficulty was found in the insertion of waste in foods: the insertion of residues in them altered its characteristics and reduced their quality, especially in breads. The author's strategy was the biological fermentation of BSG before its introduction and addition of enzymes

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

to the production process. This process allowed to elevate nutritional properties and food fibers, keeping the quality and delaying the bread aging (NEYLON et al., 2021; VRIESEKOOP et al., 2021).

4.1.3. Energy

With 31 articles fitting this category, it included research that focused in the usage of malt bagasse in processes and energy production. Energy production and use are both based in fossil fuels, responsible for a large environmental impact (CORDEIRO, 2011). The exhaustion of raw materials for the production of fossil fuels, along with worry about the consequences of anthropic activities on the environment lead to an increase in the search for renewable alternative sources of energy, biofuel among them (LIGUORI et al., 2021). From this scenario, there is an increase in the search for more sustainable economies based on technologies that use renewable sources in their productive cycles. Among these sources, biomass possesses a big energetic potential (GONZÁLEZ-GARCÍA; MORALES; GULLÓN, 2018; CORDEIRO, 2011).

Despite the rise in frequency in the use of biomass as raw material for bioenergy, it is still a challenge due to its low competitive power when compared to fossil fuels (MAIONE, 2019; BUDZIANOWSKI, 2016). Still, they have advantages such as the low added value and chemical composition: the bigger the amount of cellulose, the bigger its potential in the production of biofuel (MAIONE, 2019).

The production of ethanol from lignocellulosic biomasses is extremely attractive since it is a petroleum-derived-fuel alternative and diminishes the conflict between food/first generation ethanol fuel (LIGUORI et al., 2021). The solid malt waste offers advantage when compared to the other biomasses for its production is continuous, in large scale and with no regionalization of the industries, since beer brewers are growing globally (MAIONE, 2019).

Even with all of those advantages, the biofuel made by lignocellulosic biomass still depends on a complex process since it needs a pre-treatment to separate the cellulose, hemicellulose and lignin, besides its high amounts of humidity (GONZÁLEZ-GARCÍA, MORALES; GULLÓN, 2018; MAIONE, 2019).

López-Linares et al. (2020) proposed a biorefinery of spent brewery grains with microwave pre-treatment for the obtaining of bioproducts like arabinoxylans (AX) and the biobuthanol, which is considered an advanced biofuel for its better fueling properties than bioethanol. All waste reuse ways to allow the production of cleaner and more sustainable energy sources are considerable. The Europe Strategy 2020 considers bioeconomy as a key-element for green growth. The transformation of residues into raw materials is essential and constitutes a circular economy, an important element of sustainability (LÓPEZ-LINARES et al., 2019; CORDEIRO, 2011).

4.1.4. New Products

In this research, 20 articles were sorted into this category, with articles that focused on the inclusion of waste in new productive processes. By its composition rich in lignin, polysaccharides (cellullose and hemicellulose) and proteins, malt bagasse has a high potential of insertion in productive processes, besides being a biodegradable material and a more

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

sustainable alternative (GUARDA et al., 2021).

The polyhydroxyalkanoates (PHAs) are polyesters of great interest, for they possess characteristics similar to those of conventional plastics but are biodegradable. That being said, Corchado-Lopo et al. (2021) evaluated the efficiency in the usage of BSG as a source of carbon in the production of PHA. Guarda et al. (2021) also evaluated BSG as a source of carbon, but in the production of Volatile Fatty Acids (that are PHA's and bioplastics' precursors) and have demonstrated the high productivity of his byproduct.

Studies about BSG and plastic are still scarce, despite the potential of the waste, but some authors have evaluated its addition in the production of biodegradable film and cup holders (LEE et al., 2015; MONTEIRO et al., 2019; CORCHADO-LOPO et al., 2021).

Ferraz et al. (2013) have evaluated the efficiency of BSG in ceramic bricks for bettering the porosity, mechanic resistance, thermic isolation and water absorption and have concluded their utility without altering the product's normal conditions.

Other functionalities were also evaluated, such as the possibility of the use of bagasse as a raw material in furniture and architectural wall finishing and filling for wood-polymer composites. In these articles the eventual substitution of wood by the biodegradable byproduct was evaluated, making the process more sustainable (MONTEIRO et al., 2021; HEJNA et al., 2021).

Regarding more sustainable processes, Farias et al. (2017) suggest the development of lightweight aggregates using the main residues of beer brewing, bagasse, diatomaceous earth and residual water treatment station' muck, combined with clay, allowing its usage in green roofs (FARIAS et al., 2017). It was possible to demonstrate the efficiency of this residue aggregate that performed efficiency in water absorption, thermic isolation, and porosity, on top of being an efficient sustainable application where a high cost effectiveness can be observed.

It is possible to observe yet another low adherence to studies about the insertion of residues in these productive processes. Barbu et al. (2020) and Vieira et al. (2020) proposed the building of clustered panels. However, they observed low efficiency of panels with BSG in their studies, making the need for new academic works in this area evident in order to identify the right amount of waste, adjuncts, and efficient glues.

4.1.5. Categories of lesser predominance

In this category the themes that contemplate less than 20 articles were included, them being Growth Substrate, Environmental and Cosmetics, with 17, 17 and 3 articles respectively.

4.1.5.1. Substrate

The choice of substrate must be based on the nutrients that it contains that allow the growth of microorganisms. Another point to be considered is the use of substrates with agro-industrial residues and its potential, not only as a source of organic matter, but also of carbon, energy, and proteins (PAIVA-GUIMARÃES et al., 2019; OLIVEIRA et al., 2016). Malt waste enters as an attractive alternative in relation to its composition, containing fibers, proteins, sugars, minerals, and vitamins, besides possessing a large scale generation (PAIVA-GUIMARÃES et al.,

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

2019; OLIVEIRA et al., 2016; SILVA et al., 2021).

Silva et al. (2021) evaluated the mycelial in vitro growth of an edible mushroom, Pleurotus ostreatus, and observed the development of the mushroom in substrates of malt bagasse. An important and sustainable production for the economy can be observed here, since it uses an agro-industrial waste that is continuously generated, diminishing its environmental impacts and reducing its production costs. Besides, recent publications suggest several applications of BSG as a substrate for the cultivation of microorganisms (SILVA et al., 2021), production of natural pigments (SILBIR; GOKSUNGUR, 2019; OLIVEIRA et al., 2016), polymers with economic interest (ARAÚJO, 2018) and the production of addictives, such as as xanthan gum (MENEZES, 2013).

4.1.5.2. Environmental

In this category were observed studies that used the properties and composition of malt bagasse to serve as an adsorbent in, mainly, treatment of industrial effluents. Activated carbon is a carbon based material and, despite being one of the most well-known adsorbent in the treatment of effluents, it presents a high cost and specific preparation and regeneration techniques (BRESSAN; GEREMIAS; SOUZA, 2020). Therefore, the search for alternative precursors in the production of activated carbon is in evidence. Bressan, Geremias and Souza (2020) evaluated the adsorbing capacity of activated carbon (AC) made from malt bagasse, compared with other agro-industrial precursors, from a review, and observed the efficiency of bagasse as its precursor. Osman et al. (2019) used malt waste in the synthesis of activated carbon in the removal of heavy metals and concluded the use of this AC in remediation and treatment of effluents. Nadolny et al. (2020) evaluated the AC to adsorb paracetamol, popular analgesic that is not easily degradable and it's in water bodies. Mildemberg (2019), however, developed AC to remove methylene blue coloring from water bodies.

Another material also used in the adsorption is the biochar: the solid fraction resulting from pyrolysis, a mesoporous material, rich in carbon, highly efficient as adsorbent (MACHADO et al., 2020). The addition of a waste constantly produced in large scale would make the material cheaper and the process more sustainable (MACHADO et al., 2020; FRANCISKI et al., 2018). Machado et al. (2020) justify the use of mal bagasse for the lignin, cellulose and hemicellulose composition. The bagasse's pyrolysis resulted in the production of biochar and palmitic acid, therefore valuing the waste.

Throughout the articles, it was possible to observe the possibility of inclusion of malt waste in processes that aim at an environmental adequacy, especially in the treatment of effluents and residual waters, a matter of actual problematic. This use would make the process more sustainable. The authors point to the use of bagasse for its high availability, low cost and excellent alternative to the amount of waste generated (MACHADO et al., 2020; MILDEMBERG, 2019; COSTA, 2020).

4.1.5.3. Cosmetics

In this last category were included studies that evaluated the properties of malt

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

bagasse and its addition to pharmaceuticals from the cosmetic industry. Malt bagasse is the solid residue generated in biggest quantity in beer production and in its composition are phenolic compounds that are extremely important in the cosmetic industry. However, its applicability is still insufficiently explored (ALMENDINGER; ROHN; PLEISSNER, 2020). Phenolic compounds are chemical compounds associated with antioxidant activities, anti-aging, anti-cancer, oxidant stress prevention and competitive inhibition of tyrosinasis, responsible for darkening of skin (MACIAS-GARBETT et al., 2021; ALMENDINGER; ROHN; PLEISSNER, 2020).

The cosmetic industry has shown great interest in extracts rich in phenolic compounds, for their low toxicity bioactives that have a bleaching effect and can be used in the treatment of hyperpigmentation and inflammatory wounds, for example (ALMENDINGER; ROHN; PLEISSNER, 2020).

Bucci et al. (2020) had as an objective to extract ferulic acid from the used brewing grains with a specific pre-treatment, beyond evaluating its cosmetic use. The authors have concluded that the antioxidant properties make the compound a cosmetic bioactive. Almendinger, Rohn, Pleissner (2020) conducted a study with many malt residues as a source of cosmetic bioactives and evaluated their antioxidant capacity, tyrosinasis inhibition and keratinocytes. The waste was considered a promising material for the cosmetic industry, however, this area still needs studies to evaluate the most efficient activity for these extracts even further.

5. CONCLUSION

The beer industry has an expressive participation in Brazilian economy, and, with its production, there is also a significant generation of waste during the brewing process. Malt bagasse is the main solid residue in the beer industry, representing over 80% of all generated residues.

The humidity of malt waste is the main difficulty for its reuse, requiring pre-treatments to allow its use and guarantee product quality. From the research conducted, it was possible to observe the effort and new studies in search of the insertion of these residues in new industrial sectors that adapt to the bagasse's characteristics.

The Evaluation, Human Feeding and Energy categories correspond to the areas with the biggest amount of articles found, respectively. The malt evaluation by the authors allowed to observe why there is an interest in that byproduct. Its composition, rich in polysaccharides, lignin, cellulose, and hemicellulose, makes this material a great source of fibrous material. Besides, the residue is rich in carbohydrates, proteins, lipids, and vitamins, showing the versatility of this product.

Human Feeding was one of the main uses in the articles, considering the acceptability by consumers and efficacy of the inclusion of bagasse. The addition is efficient due to the presence of fibers and the betterment of the nutritional value of the food.

In the Energy category, a benefit of the use of malt bagasse by its large scale and continuous production was found. However, some authors have pointed at difficulties due to the lignocellulosic composition that requires pre-treatments for a better energetic usage.

With this paper, it was possible to observe that there has been an increase in the

number of studies about the reuse of malt bagasse. This product is efficient and versatile, both important characteristics for its insertion in several sectors, considering its low cost and nonstop production. The results found were within expectations, the use of this waste in new processes that will allow for the reduction of inadequate disposal and the diminishing of environmental impact, allowing for cleaner and more sustainable production chains (P + C). The reuse of this byproduct, that is produced in massive quantities, would make the process not only more economically efficient, but also sustainable, agreeing with the goals proposed in the 2030 Agenda.

BIBLIOGRAPHIC REFERENCES

AČKAR, Đ.; JOZINOVIĆ, A.; BABIĆ, J.; MILIČEVIĆ, B.; BALENTIĆ, J. P.; ŠUBARIĆ, D. Resolving the problem of poor expansion in corn extrudates enriched with food industry by-products. **Innovative food science & emerging technologies**, v. 47, p. 517-524, 2018.

ALMEIDA, A.; GERALDO, M. R. F.; RIBEIRO, L. F.; SILVA, M. V.; MACIEL, M. V. D. O. B.; HAMINIUK, C. W. I. Bioactive compounds from brewer's spent grain: phenolic compounds, fatty acids, and in vitro antioxidant capacity. **Acta Scientiarum. Technology**, v. 39, n. 3, p. 269-277, 2017.

ALMENDINGER, M.; ROHN, S.; PLEISSNER, D. Malt and beer-related by-products as potential antioxidant skin-lightening agents for cosmetics. **Sustainable Chemistry and Pharmacy**, v. 17, p. 100282, 2020.

ARAÚJO, J. F. **Produção de quitosana e bioemulsificante por Rhizopus microsporus (UCP 1304) através da fermentação submersa utilizando resíduos agroindustriais**. 2018. 58 f. Dissertação (Mestrado) - Universidade Católica de Pernambuco. Pró-reitora Acadêmica. Curso de Mestrado em Desenvolvimento de Processos Ambientais, 2018.

BARBU, M. C.; MONTECUCCOLI, Z.; FÖRG, J.; BARBECK, U.; KLÍMEK, P.; PETUTSCHNIGG, A.; TUDOR, E. M. Potential of Brewer's Spent Grain as a Potential Replacement of Wood in pMDI, UF or MUF Bonded Particleboard. **Polymers**, v. 13, n. 3, p. 319, 2021.

BIELI, B. C.; MARQUES, D. R.; MARCHI, L. B.; QUELHAS J. O. F.; CHINELLATO, M. M.; MONTEIRO, C. C. F.; MONTEIRO, A. R. G. Produção de snack extrusado com adição de farinha de bagaço de malte. **Revista Tecnológica**, p. 321-326, 2014.

BRESSAN, P.; GEREMIAS, R.; DE SOUZA, E. L. Resíduo da indústria cervejeira como precursor de carvão ativado comparado a outros resíduos agroindustriais: uma revisão. **Evidência**, v. 20, n. 2, p. 141-148, 2020.

BUCCI, P. L.; SANTOS, M. V.; MONTANARI, J.; ZARITZKY, N. Nanoferulic: From a by-product of the beer industry toward the regeneration of the skin. **Journal of cosmetic dermatology**, v. 19, n. 11, p. 2958-2964, 2020.
BUDZIANOWSKI, W. M. High-value low-volume bioproducts coupled to bioenergies with potential to enhance business development of sustainable biorefineries. **Renewable and Sustainable Energy Reviews**, v. 70, p. 793–804, 2016

CORCHADO-LOPO, C. et al. Brewer's spent grain as a no-cost substrate for polyhydroxyalkanoates production: assessment of pretreatment strategies and different bacterial strains. **New Biotechnology**, v. 62, p. 60-67, 2021.

CORDEIRO, L. G. **Caracterização e viabilidade econômica do bagaço de malte oriundo de cervejarias para fins energéticos. 2011. 120f**. 2017. Tese de Doutorado. Dissertação (Mestrado em Ciência e Tecnologia de Alimentos). Universidade Federal da Paraíba, João Pessoa, 2011.

DALLAMUTA, J.; HOLZMANN, H., A.; KANASHIRO, O., R. (org.). Ampliação e aprofundamento de conhecimentos nas áreas das engenharias. 2020

DEL RIO, J. C.; PRINSEN, P.; GUTIÉRREZ, A. Chemical composition of lipids in brewer's spent grain: A promising source of valuable phytochemicals. **Journal of Cereal Science**, v. 58, n. 2, p. 248-254, 2013.

FARÍAS, R. D.; MARTÍNEZ GARCÍA, C.; COTES PALOMINO, T.; MARTÍNEZ ARELLANO, M. Effects of wastes from the brewing industry in lightweight aggregates manufactured with clay for green roofs. **Materials**, v. 10, n. 5, p. 527, 2017.

FERRAZ, E.; COROADO J.; GAMELAS, J.; SILVA, J.; ROCHA, F.; VELOSA, A. Spent brewery grains for improvement of thermal insulation of ceramic bricks. **Journal of materials in civil engineering**, v. 25, n. 11, p. 1638-1646, 2013.

FRANCISKI, M. A.; PERES, E. C.; GODINHO, M.; PERONDI, D.; FOLETTO, E. L.; COLLAZZO, G. C.; DOTTO, G. L. Development of CO2 activated biochar from solid wastes of a beer industry and its application for methylene blue adsorption. **Waste Management**, v. 78, p. 630-638, 2018.

GONZÁLEZ-GARCÍA, S.; MORALES, P. C.; GULLÓN, B. Estimating the environmental impacts of a brewery waste–based biorefinery: Bioethanol and xylooligosaccharides joint production case study. **Industrial Crops and Products**, v. 123, p. 331-340, 2018.

GRASSO, S. Extruded snacks from industrial by-products: A review. **Trends in Food Science & Technology**, v. 99, p. 284-294, 2020.

GUARDA, E. C.; OLIVEIRA, A. C.; ANTUNES, S.; FREITAS, F.; CASTRO, P. M.; DUQUE, A. F.; REIS, M. A. A Two-Stage Process for Conversion of Brewer's Spent Grain into Volatile Fatty Acids through Acidogenic Fermentation. **Applied Sciences**, v. 11, n. 7, p. 3222, 2021.

HEJNA, A.; BARCZEWSKI, M.; SKÓRCZEWSKA, K.; SZULC, J.; CHMIELNICKI, B.; KOROL, J.; & FORMELA, K. Sustainable upcycling of brewers' spent grain by thermo-mechanical treatment in twin-screw extruder. **Journal of Cleaner Production**, v. 285, p. 124839, 2021.

JAEGER, A.; ZANNINI, E.; SAHIN, A. W.; ARENDT, E. K. Barley Protein Properties, Extraction and Applications, with a Focus on Brewers' Spent Grain Protein. **Foods**, v. 10, n. 6, p. 1389, 2021.

JOZINOVIĆ, A.; ŠUBARIĆ, D.; AČKAR, Đ.; BABIĆ, J.; ORKIĆ, V.; GUBERAC, S.; MILIČEVIĆ, B. Food Industry By-Products as Raw Materials in the Production of Value-Added Corn Snack Products. **Foods**, v. 10, n. 5, p. 946, 2021.

KIRIN BEER UNIVERSITY. **Global Beer Production by country in 2018.** Kirin Beer University Report, v.11, 2019.

KIRJORANTA, S.; TENKANEN, M.; JOUPPILA, K. Effects of process parameters on the properties of barley containing snacks enriched with brewer's spent grain. **Journal of food science and technology**, v. 53, n. 1, p. 775-783, 2016.

LEE, J. H.; LEE, J. H.; YANG, H. J.; SONG, K. B. Preparation and characterization of brewer's spent grain protein-chitosan composite films. **Journal of Food Science and Technology**, v. 52, n. 11, p. 7549-7555, 2015.

LIGUORI, R.; SOCCOL, C. R.; PORTO S. V.; WOICIECHOWSKI, A. L.; FARACO, V. Second generation ethanol production from brewers' spent grain. **Energies**, v. 8, n. 4, p. 2575-2586, 2015.

LIMA, R. C. F. **Produção da enzima α-amilase por Aspergillus niger em fermentação no estado sólido utilizando bagaço de malte de cevada**. 2019. Tese de Doutorado. Dissertação (Mestrado em Engenharia Química) - Centro de Ciências Agrárias e Engenharias, Universidade Federal do Espírito Santo, Alegre-ES.

LÓPEZ-LINARES, J. C.; GARCÍA-CUBERO, M. T.; LUCAS, S.; GONZÁLEZ-BENITO, G.; COCA, M. Microwave assisted hydrothermal as greener pretreatment of brewer's spent grains for biobutanol production. **Chemical Engineering Journal**, v. 368, p. 1045-1055, 2019.

LÓPEZ-LINARES, J. C.; LUCAS, S.; GARCÍA-CUBERO, M. T.; JIMÉNEZ, J. J.; COCA, M. A biorefinery based on brewers spent grains: Arabinoxylans recovery by microwave assisted pretreatment integrated with butanol production. **Industrial Crops and Products**, v. 158, p. 113044, 2020.

LORDAN, R.; O'KEEFFE, E.; TSOUPRAS, A.; ZABETAKIS, I. Total, neutral, and polar lipids of brewing ingredients, by-products and beer: Evaluation of antithrombotic activities. **Foods**, v. 8, n. 5, p. 171, 2019.

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

MACHADO, L. M.; LÜTKE, S. F.; PERONDI, D.; GODINHO, M.; OLIVEIRA, M. L.; COLLAZZO, G. C.; DOTTO, G. L. Simultaneous production of mesoporous biochar and palmitic acid by pyrolysis of brewing industry wastes. **Waste Management**, v. 113, p. 96-104, 2020.

MACIAS-GARBETT, R.; SERNA-HERNÁNDEZ, S.O.; SOSA-HERNÁNDEZ, J. E.; PARRA-SALDIVAR, R. Mini review: Phenolic compounds from brewer's spent grains: towards green recovery methods and applications in the cosmetic industry. **Frontiers in Sustainable Food Systems**, v. *5*, p.196, 2021

MAIONE, N. R. **Pré-tratamento hidrotérmico do bagaço de malte (BSG) visando a produção de etanol de segunda geração**. 2019. 54 f. Dissertação (Mestrado em Engenharia Química) - Universidade Federal de Goiás, Goiânia, 2019.

MATHIAS, T. R.; ALEXANDRE, V. M. F.; CAMMAROTA, M.C.; MELLO, P. P. M.; SÉRVULO, E. F. C. Characterization and determination of brewer's solid wastes composition. **Journal of the Institute of Brewing**, v. 121(3), p.400-404, 2015

MENEZES, J. D. S. **Produção de goma xantana a partir da bioconversão de resíduo e malte de cervejaria por Xanthomonas Campestris pv, campestres IBSBF 1866**. 2013. 97f. Tese (Doutorado em Desenvolvimento e Meio Ambiente) - Universidade Federal de Sergipe, São Cristovão, 2013.

MILDEMBERG, A. N. **Obtenção de carvão ativado a partir de bagaço de malte e sua aplicação na remoção de azul de metileno**. Dissertação (Mestrado em Meio Ambiente Urbano e Industrial) – Universidade Federal do Paraná, 21019

MONTEIRO, C. C.; SARACHE, G.; JANUARIO, J. G.; BERWIG, K. P.; RANIERO, G. Z.; MONTEIRO, A. R.; SILVA, F. M. Biopolymer Based on Brewing Waste and Extruded Maize: Characterization and Application. **Chemical Engineering Transactions**, v. 87, p. 319-324, 2021.

MONTEIRO, C. et al. Biomaterial Based on Brewing Waste and Vegetable Resin: Characterization and Application in Product Design. **Chemical Engineering Transactions**, v. 75, p. 475-480, 2019.

MUSSATTO, S. I. Brewer's spent grain: a valuable feedstock for industrial applications. **Journal of the Science of Food and Agriculture**, v. 94, n. 7, p. 1264-1275, 2014.

NADOLNY, B.; HEINECK, R. G.; BAZANI, H. A. G.; HEMMER, J. V.; BIAVATTI, M. L.; RADETSKI, C. M.; ALMERINDO, G. I. Use of brewing industry waste to produce carbon-based adsorbents: Paracetamol adsorption study. **Journal of Environmental Science and Health, Part A**, v. 55, n. 8, p. 947-956, 2020.

NASCIMENTO FILHO, W. B.; FRANCO, C. R. Avaliação do potencial dos resíduos produzidos através do processamento agroindustrial no Brasil. **Revista Virtual de Química**, v. 7, n. 6, p. 1968-1987, 2015.

NEYLON, E.; ARENDT, E. K.; ZANNINI, E.; SAHIN, A. W. Fermentation as a Tool to Revitalise Brewers' Spent Grain and Elevate Techno-Functional Properties and Nutritional Value in High Fibre Bread. **Foods**, v. 10, n. 7, p. 1639, 2021.

OLIVEIRA, C. F. D.; VENDRUSCOLO, F.; COSTA, J. P. V.; ARAÚJO, W. D. B. Bagaço de malte como substrato para produção de biopigmentos produzidos por Monascus ruber CCT 3802. **Revista de Agricultura Neotropical**, v. 3, n. 3, p. 6-9, 2016.

OLIVEIRA, D. M.; MARQUES, D. R.; KWIATKOWSKI, A.; MONTEIRO, A. R. G.; CLEMENTE, E. Sensory analysis and chemical characterization of cereal enriched with grape peel and seed flour. Acta Scientiarum Technology. Maringá, v. 35, n. 1, p.427-431, 2013.

OLIVEIRA, E. B. D.; CASTRO, A. C. F.; RAIMUNDINI, S. L.; STRUMIELLO, L. D. P. Desenvolvimento sustentável e produção mais limpa: estudo de caso em uma empresa do setor moveleiro. **ConTexto**. v. 9, n. 16, p. 1-12, 2009

ONU. Organização das Nações Unidas. Transformando nosso mundo: a Agenda 2030 para o desenvolvimento sustentável. 2016. Disponível em: https://www.mds.gov.br/webarquivos/publicacao/Brasil_Amigo_Pesso_Idosa/Agenda2030.pdf

OSMAN, A. I. et al. Upcycling brewer's spent grain waste into activated carbon and carbon nanotubes for energy and other applications via two-stage activation. **Journal of Chemical Technology & Biotechnology**, v. 95, n. 1, p. 183-195, 2019.

ISSN 1980-0827 – Volume 19, Number 5, Year 2023

PAIVA-GUIMARÃES, A. G. L.; FREIRE, K. R. L.; SANTOS, S. F. M.; ALMEIDA, A. F.; SOUSA, A. C. B. Alternative substrates for conidiogenesis of the entomopathogenic fungus Beauveria bassiana (Bals) Vuillemin (Deuteromycotina: Hyphomycetes). **Brazilian Journal of Biology**, v. 80, p. 133-141, 2019.

PORTO, P. D. D. **Tecnologia de fabricação de malte: uma revisão**. 2011. Dissertação (Graduação em Engenharia de Alimentos) – Instituto de Ciências e Tecnologia de Alimentos, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2011.

QUARANTA, N.; CALIGARIS, M.; PELOZO, G.; UNSEN, M.; CRISTOBAL, A. The characterization of brewing waste and feasibility of its use for the production of porous ceramics. **WIT Trans Ecol Envir**, v. 202, p. 299-310, 2016.

SILBIR, S.; GOKSUNGUR, Y. Natural red pigment production by Monascus purpureus in submerged fermentation systems using a food industry waste: Brewer's spent grain. **Foods**, v. 8, n. 5, p. 161, 2019.

SILVA, B. C. **Biossorção do corante Amarelo Reafix B8G a partir do bagaço de malte em batelada e sistema contínuo: avaliação experimental e simulação fluidodinâmica computacional**. 2019. 171 f. Dissertação (Mestrado em Engenharia Química) - Universidade Tecnológica Federal do Paraná, Ponta Grossa, 2019.

SILVA, L. F.; DA SILVA, G. C. P. A.; MARTINS, O. G.; SOUZA PASSOS, J. R.; ANDRADE, M. C. N. Crescimento micelial de *Pleurotus ostreatus* em substratos suplementados com bagaço de malte. **Revista em Agronegócio e Meio Ambiente**, v. 14, n. 3, p. 1-12, 2021.

TOMBINI, C.; GODOY, J., S.; ULLMANN, A., P.; FANTE, G.; MELLO, J., M., M.; DALCANTON, F. Utilização do bagaço de malte na alimentação humana: revisão sistemática da literatura. In:

VIEIRA, H. C.; RIOS, P. D. A.; CUNHA, A. B.; KNIESS, D. D. C.; GAA, A. Z. N.; RICARDO, G. C.; JUNIOR, A. L. B. Resíduo de cevada industrial para a produção de painéis aglomerados. **Revista de Ciências Agroveterinárias**, v. 19, n. 3, p. 365-372, 2020.

VRIESEKOOP, F.; HAYNES, A.; HEIJDEN, N.; LIANG, H.; PAXIMADA, P.; ZUIDBERG, A. Incorporation of Fermented Brewers Spent Grain in the Production of Sourdough Bread. **Fermentation**, v. 7, n. 2, p. 96, 2021.