Artigo científico

Carolina Carla valera Sanchez[1], Vitória Souza Lima[2], Jean Carlos Rodrigues da Silva[3]

[1, 2, 3] Instituto Federal de Educação, Ciência e Tecnologia de São Paulo, IFSP – Câmpus Sertãozinho

Beer production using saccharine sorghum (*Sorghum bicolor*): potential and possibilities

Produção de cerveja com sorgo sacarino (Sorghum bicolor): potencial e possibilidades

Abstract. *Sorghum bicolor* L. Moench presents potential characteristics for brewing as adjunct or as an integral malted constituent of beer. The grain is already used in this industry to reduce costs and balance new flavors and aromas, but some biochemical characteristics negatively interfere with the proper brewing process such as: great loss of malt during malting process; high gelatinization temperatures; low extract yield; low diastatic power (DP); low free amino-nitrogen (FAN); high viscosity of mash and filtration problems. In this review, we aimed to go through the academic literature on the possibilities of overcoming these problems. We found that most of these limitations were solved by techniques characterized by controlled infusion method, double-infusion mashing, grain extrusion, bioacidification, controlled use of exogenous enzymes and selection of special yeasts adapted to the sugar content of sorghum, indicating that brewing using saccharine sorghum is possible and results in cost savings and new quality options in the market. **Keywords**: beer, sorghum, malt, brewing, fermentation.

Resumo. *AO Sorghum bicolor* L. Moench apresenta características potenciais para produção de cerveja, com aplicações tanto como adjunto quanto como constituinte maltado. Atualmente o sorgo já é utilizado nesta indústria para reduzir custos e produzir novos sabores e aromas, entretanto, algumas características bioquímicas interferem negativamente no processo de produção de cerveja, tais como: grande perda de malte durante o processo de malteação; altas temperaturas de gelatinização; baixo rendimento de extrato; baixo poder diastático (DP); baixo teor de amino nitrogênio livre (FAN); alta viscosidade do mosto e problemas de filtração. Nesta revisão, objetivamos percorrer a literatura acadêmica sobre as possibilidades de superação desses problemas. Constatamos que a maioria dessas limitações foi resolvida por técnicas caracterizadas por método de infusão controlada, maceração em dupla infusão, extrusão de grãos, bioacidificação, uso controlado de enzimas exógenas e seleção de leveduras especiais adaptadas ao teor de açúcar de sorgo, indicando que a fabricação de cerveja com sorgo sacarino é possível e resulta em redução de custos e novas opções de qualidade no mercado. **Palavras-chave:** cerveja, sorgo, malte, produção de cerveja, fermentação.

Introdução

In general, adjuncts tend to reduce the cost of production, as they are cheaper than barley malt, as well as enabling the production of beers with different flavors and aromas (YORK; COOK; FORD, 2021). Brazil, as the third biggest producer and one of the largest beer consumers in the world, buys about 400.000 ton/year of imported barley to supply demand of manufacturers and, thus, research on adjunct brewers is essential (VASCONCELOS, 2017). Among the diversity of adjuncts, sorghum (*Sorghum bicolor* L. Moench) shows potential characteristics.

Sorghum is a highly versatile specie that has five different types: grain sorghum, used for grain production; fodder sorghum, used to produce mass for silage; lignocellulosic sorghum or biomass sorghum, used to produce lignocellulosic biomass; saccharine sorghum, used to produce biofuels; broom sorghum, used to produce brooms. This variability between types of sorghum is valuable for being able to meet different markets, interests and needs across the planet (MAY, 2013).

Saccharine sorghum is similar to sugarcane, containing stalks with juice rich in fermentable sugars, being able to be used for ethanol production in the same equipment used for sugarcane and, in the same way of sugarcane, to supply bagasse as an energy source for industry. Furthermore, sowing sorghum is recommended for most sugarcane producing areas during renovation of the sugarcane plantation (LANDAU; SCHAFFERT, 2011).

Sorghum produces grains that have nutritional characteristics similar to corn and can be used in human or animal food (DURÕES, 2011). In Nigeria, saccharine sorghum and corn have been widely used for brewing since the 1990s, to reduce costs and create new flavors and aromas (TOKPOHOZIN; FISCHER; BECKER, 2019a).

Among the raw materials used in breweries, *Sorghum bicolor* grains are becoming a target of interest regarding functional foods and beverage production. This gluten-free raw material contains large amounts of anthocyanins, such as luteolinidine and apigenidin, which are known for their functionality and positive health-promoting properties. These properties include the prevention and reduction of oxidative stress and cardiovascular diseases, as well as anti-cancer, anti-diabetic, anti-inflammatory and anti-hypertensive effects (TOKPOHOZIN; FISCHER; BECKER, 2019a).

Thus, because of the attractive conditions for planting sorghum in Brazil, as well as its chemical and nutritional characteristics, this species presents itself as a challenging beer adjunct and research in the scientific literature regarding the possibilities of this application on brewing is the purpose of this article (review). For this purpose, the following terms were searched in databases of scientific journals: “sorghum and brewing”, “sorghum and beer adjunct”, “sorghum and malting”, “sorghum and mashing” and “sorghum wort”. The search was limited to the English language, with the terms searched in the fields "title", "abstract" and "keywords", published between 2006 and 2021.

Beer and sorghum

The growth of the brewing activity in Brazil has advanced in recent years with the increase in the number of brewery and beer registrations. In 2020, there was an increase of 14.4% in the number of breweries compared to the previous year, which totaled 1383 units (BRASIL, 2021). In the last decade, the craft beer segment had an annual evolution of 20% in the average consumption rate (VASCONCELOS, 2017).

The craft beer manufacturing process consists in the steps of malt milling, mashing, boiling, cooling, fermentation, maturation and filling. In addition, temperature control during brewing, as well as the quality of raw materials, has too much influence on flavor, aromas and cost of the final product.

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important cereal crop in the world, after corn, rice, wheat and barley. This is one of the cereals that can be used in beer production, both as a substitute of barley, resulting in a gluten-free beer, or as an adjunct (SALAZAR-LÓPEZ et al., 2018; ROONEY; SALDIVAR, 2003). However, brewing based on sorghum grains presents biochemical problems during its processing. According to Ogbonna (2011), the main problems can be listed as: large malt loss during malting, which varies between 10 to 30%, against 8 to 10% for barley; high gelatinization temperatures, which limits starch hydrolysis by amylolytic enzymes; low extract yield; low diastatic power (DP); low free amino-nitrogen (FAN); high wort viscosity and filtration problems. Therefore, the impasses arising from the sorghum-based brewing production are due to the grain malting and mashing processes, which can impact the fermentation of the wort (OGBONNA, 2011). In the next sections, we present investigations to minimize the losses from these steps.

Malting

Malting loss reflects dry matter losses because of the translocation of soluble materials to the germination. A controlled maceration method, which consists of the addition of hot water and air rest cycles, proved to be positive for reducing sorghum malt losses. In this system applied by Badau, Nkama and Jideani (2006), the clean grains were drowned in water at 30°C for 12 hours at a grain to water ratio of 1:10, with one hour of rest (unsoaked grains) at every 6 hours of soaking. At the end of 12 hours, the grains were sterilized by immersion in a 1% sodium hypochlorite solution for 20 minutes. After that, kernels were germinated at room temperature for 0, 24, 48, 72 and 96 hours. Thus, significant improvements in terms of malt loss were observed which increased germination time (BADAU; NKAMA; JIDEANI, 2006).

Diastatic power (DP) is the ability of α and β-amylases to convert starch into sugars. The α-amylase promotes the breakdown of starch into smaller units of soluble sugars, which through β-amylase are hydrolyzed into fermentable sugars and consumed by yeasts. The adequate activity of these enzymes guarantee the fermentative success of production, but, in general, sorghum grains present less β-amylase activity than barley, which makes the sorghum naturally less fermentable (DISHAROON *et al.*, 2021). However, studies suggest that the ICSV400 and KSV8 varieties have extract yield increased when the grains were malted by the malting regime mentioned above. Even higher extract yield values have been reported from the use of cysteine hydrochloride as extractant. These results suggest that the extract yield using sorghum malt may be similar or greater than that obtained from barley malt (OGBONNA, 2011).

Regarding the proportions of sugars in the brewer's wort, Okolo et al. (2020), compared the composition of wort produced from 100% malted barley and wort produced from 90% sorghum with malted barley and commercial enzymes. A similar glucose to maltose ratio was noted in both cases. This ratio is important because in a wort in which glucose is more than maltose, some yeast strains may lose their ability to ferment maltose. The alcohol content was 9.45% and 9.05% for beers with only malted barley and that produced with 90% of sorghum, respectively, which demonstrates that both compositions can be used to produce similar high gravity worts. For this determination, the fermentation was carried out with *Saccharomyces cerevisiae* at 30°C for 72 hours (OKOLO et al., 2020).

However, it is important to highlight the wort compositions with the addition of commercial enzymes during its processing, as this action can change the availability of certain types of fermentable sugars, and, therefore, modify the fermentation efficiency. According to Okolo et al. (2019), mashing unmalted barley and sorghum grains with commercial enzymes (heat stable α-amylase, endo-β-glucanase and proteolytic enzymes) the sugar profiles found was completely different. Therefore, it is clear that the same mashing process cannot be used for sorghum and barley grains (OKOLO et al., 2020).

According to Disharoon et al. (2020), the major limitation for a broader adoption of sweet sorghum as a substrate in brewing mashing comprises the low activity of its amylolytic enzymes, especially α and β-amylases, when compared to barley. To overcome the challenges of sorghum's low amylase activity, many beverages are made with addition of amylase-producing *Lactobacillus* or similar microorganisms, which generate a sour taste. In commercial sorghum-based beers that do not use these microorganisms, amylolytic enzymes must often be supplemented with the addition of other grain adjuncts or grain-derived enzymes for effective saccharification. However, the addition of these elements can be cost prohibitive and when grain supplements such as barley are used, gluten is introduced into the product (DISHAROON et al., 2021).

To identify types of sorghum that can be better applied to malting processes, the presence of amylase inhibitors found in the grain must be considered. In this sense, tannins and phenols are documented as possible amylase inhibitors. Studies towards the reduction of these compounds in sorghum can increase their amylolytic activity (DISHAROON et al., 2021). Furthermore, studies linking grain color with assessments of amylase levels have found red sorghum varieties that exhibit higher levels of these enzymes and a considerable diastatic power (DISHAROON et al., 2021).

Gelatinization

Starch is stored in the plant as compact micron-sized granules that are partly crystalline and, hence, water-insoluble. The first step in starch utilization disrupts the granular structure leading to granule swelling and the hydration and solubilization of starch molecules. These events are affected by heating the granules that are slurried in water, and are collectively referred to as starch gelatinization (ZOBEL, 1984)

Sorghum grains do not have husks and have a high concentration of starch whose granules are incorporated by a dense protein matrix rich in disulfide bonds, causing gelatinization in temperatures between 65.8 - 71.0 °C, that are higher than barley starch (59.0 - 64.6 °C) (SCHNITZENBAUMER; ARENDT, 2014; MA et al., 2016). Due to this, brewing with sorghum necessitates the use of a double infusion mashing procedure, where the sorghum starch is pregelatinized by cooking, cooled and then saccharified with barley malt or commercial enzymes (DLAMINI; KRUGER; TAYLOR, 2013; SCHNITZENBAUMER et al., 2014). However, Schnitzenbaumer and Arendt (2014) demonstrated that mashing using up to 50% commercial sorghum flour in a simple infusion process was successful.

In addition to grain gelatinization performed by adding heated water, cereal starch can also be gelatinized by adding a solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH), which can promote better water absorption by starch granules. This characteristic is used to classify rice varieties into those with high, intermediate or low starch gelatinization temperature and alkali spreading value (ASV) of the grain is scored (LITTLE et al., 1958). In this sense, de Griebel et al. (2019) carried out a study in which sorghum seeds, previously treated with ethyl methanesulfonate (EMS) treatment to create a mutant population, were cut longitudinally and treated with KOH solutions at different concentrations to determine the ASV. It was founded mutants that exhibit a significant difference of maximum gelatinization temperature than control samples (GRIEBEL et al., 2019). The identification of sorghum genotypes with lower starch gelatinization temperatures properties would be advantageous to the sorghum malting industry (GRIEBEL et al., 2019).

Saccharification

To improve the saccharification of sweet sorghum wort, Tokpohozin, Fischer and Becker (2019) optimized β-amylase activity with preheating (to gelatinize the starch) and bioacidification of wort with *Lactobacillus plantarum* and *Lactobacillus paracasei*. Before heating the wort at gelatinization temperature, a fraction was separated and added again after wort cooling. Preheating and bioacidification increased the free amine nitrogen (FAN) content of the wort by up to 27%. The content of several amino acids, including the branched amino acids valine, leucine and isoleucine increased significantly, so that the total branched amino acid content of the wort increased by up to 50%. The branched amino acids valine, isoleucine and leucine are precursors of isobutane, amyl alcohol and isoamyl alcohol, critical components of beer aroma (TOKPOHOZIN; FISCHER; BECKER, 2019a).

The increase in FAN after preheating demonstrated that this process helps to improve enzymatic extraction and to prevent amino acid degradation during gelatinization. Acidification of wort with proteolytic bacteria resulted in two positive effects: proper mash pH increased sorghum malt enzyme activity and biological acidification prior to saccharification allowed lactic acid bacteria to produce protease for degradate sorghum malt proteins (TOKPOHOZIN; FISCHER; BECKER, 2019a).

Filtration

After mashing, filtration is an important step in the process. It has been reported that mashing with 100% of sorghum malt results in slow filtrations (TOKPOHOZIN; FISCHER; BECKER, 2019a). Beyond undegraded starch and protein, β-glucans are also associated with an increase in filtration time. However, sorghum bioacidification reduced the filtration time due to the production of protease and β-glucanase by lactic acid bacteria and the consequent degradation of β-glucans (TOKPOHOZIN; FISCHER; BECKER, 2019a).

Holmes, Casey and Cook (2017), with similar purposes, produced beer worts from five unmalted sorghums (2 brewing and 3 non-brewing varieties) with low temperature and addition of exogenous enzymes, and obtained a wort of quality comparable to those resulting from traditional practices that require the use of high temperatures. In addition, they noticed that such performance was little dependent on sorghum quality, non-brewing varieties can potentially be applied. The energy savings from operating the low temperature system would be substantial on an industrial scale because the maximum temperature reached for the mashing scheme has been reduced from 95°C to 78°C, and the energy requirements to heat a wort to 95°C and then cooling it to 65°C for saccharification are eliminated (HOLMES; CASEY; COOK, 2017).

Fermentation

The level of free amine nitrogen (FAN) in the wort is considered an important parameter for predicting the growth of healthy yeast, as well as the vitality and efficiency of fermentation (KRUGER *et al.*, 2012). In raw sorghum wort, FAN and mineral content can be very low due to poor protein digestibility (degradation) and phytate-mineral chelation. Phytate is a chelating agent that, through multiple bonds, forms insoluble, complex molecules with some proteins and particularly divalent metal ions (KRUGER et al., 2012). In this sense, Kruger et al. (2012) evaluated the potential for improving yeast nutrition in raw sorghum grains for brewing beer and bioethanol production through genetic manipulation of sorghum aiming to improve protein digestibility and phytate reduction. The genetic modifications relevant to this study were the suppression of myo-inositol kinase synthesis, which decreases phytic acid, and the suppression of kaphyrin synthesis, which results in improvements in protein degradation. As result, the genetically modified sorghum showed 72% lower phytate content and better protein when compared to controls. With phytase treatment and genetic modification, there was a substantial increase in the proportions of all minerals solubilized in the wort, which demonstrates that the treatments applied can potentially be used to improve the levels of mineral nutrition of brewer's yeast (KRUGER et al., 2012).

Flavor and aroma

Beer flavor comes from a complex interaction among hundreds of chemical compounds. All brewer's yeast produces glycerol, vicinal diketones (VDKs), short-chain fatty acids, organic acids and sulfur-containing substances (negative for the quality of the final product) as well as relevant aroma components, i.e., higher alcohols and esters (TOKPOHOZIN; FISCHER; BECKER, 2019b). As already mentioned, protein hydrolysis during the saccharification of sorghum beer wort is limited, which comprises the amino acid content. Amino acids are precursors of several relevant aromas like alcohols and esters, as well as influence the expression and regulation of different genes that encode enzymes which catalyze their synthesis, so, it is evident that the low content of amino acids in sorghum wort impairs aroma synthesis by the yeast during fermentation (TOKPOHOZIN; FISCHER; BECKER, 2019b). In addition, sorghum is generally characterized by a high concentration of polyphenols, which can inhibit yeast growth and enzyme activity in the fermentation process, as well as generate beers with astringent and bitter flavors (SCHNITZENBAUMER et al., 2014). Considering these characteristics, Tokpohozin, Fischer and Becker (2019b) studied the autochthonous yeast *Saccharomyces* from traditional African sorghum for the production of sorghum beer. The results demonstrated that the isolated yeasts strains produced large amounts of amyl alcohol, isoamyl alcohol, isoamyl acetate and ethyl acetate when the fermentation was carried out at 27°C, indicating that these strains of *S. cerevisiae* are well adapted to tropical temperatures from West Africa and the lower amino acid content of sorghum wort. In contrast, the yeast TUM68 (highly used in industrial brewing) generally requires higher amounts of leucine, isoleucine, valine, histidine, glutamine and proline to efficiently synthesize flavor compounds (TOKPOHOZIN; FISCHER; BECKER, 2019b).

Ma et al. (2016) published a study in which they used gas chromatography coupled with mass spectrometry to identify chemical compounds responsible for beer flavors in two types of beers made from white sorghum as adjunct. One of the samples was produced with extruded sorghum of grains aiming to facilitate the access of enzymes to the starch and the other with non-extruded sorghum. Altogether, 45 different flavors were found from beer produced with extruded sorghum and 31 from non-extruded sorghum beer, indicating that the extrusion method can be beneficial for the extraction of more chemical compounds positive for the sensory characteristics of beer. In addition, it can be seen that the use of sorghum as an adjunct is beneficial to the quality of the final product for beer quality, as it by providing variability in sensory characteristics, which can be used for the production of innovative products (MA et al., 2016).

Conclusion

It was shown that most of the biochemical problems related to this process can be solved through the application of techniques that significantly minimize these difficulties, such as special malting regimes, extrusion, genetic modification, bioacidification, exogenous enzymes and the use of different strains of yeast. Therefore, brewing sweet sorghum, either malted or as an adjunct, is not only technically feasible, but also has potential for cost savings and alternative sensory profile with good characteristics.

Funding: This research was funded by the Federal Institute of Education, Science and Technology of São Paulo.

Conflicts of Interest: The authors declare no conflict of interest.

Referências bibliográficas

BADAU, M.; NKAMA, I.; JIDEANI, I. A. Steep-Out Moisture, Malting Loss, and Diastatic Power of Pearl Millet and Sorghum as Affected by Germination Time and Cultivar. *International Journal of Food Properties, [S. l.]*, v. 9, n. 2, p. 261–279, 2006.

BRASIL, M. da A. P. e A. *Anuário de Cerveja 2020. [S. l.: s. n.]*.

DISHAROON, A. *et al.* Exploring diverse sorghum (Sorghum bicolor (L.) Moench) accessions for malt amylase activity. *Journal of the Institute of Brewing*, *[S. l.]*, v. 127, p. 5–12, 2021.

DLAMINI, C. B.; KRUGER, J.; TAYLOR, R. N. J. Review: The science of the tropical cereals sorghum, maize and rice in relation to lager beer brewing. *The Institute of Brewing & Distilling, [S. l.]*, 2013.

DURÕES, F. Sorgo sacarino: desenvolvimento de tecnologia agronômica. *Agroenergia em revista, [S. l.]*, n. 3, p. 7, 2011.

GRIEBEL, S. *et al.* The alkali spreading phenotype in Sorghum bicolor and its relationship to starch gelatinization. *Journal of Cereal Science, [S. l.]*, v. 86, p. 41–47, 2019.

HOLMES, C. P.; CASEY, J.; COOK, D. J. Mashing with unmalted sorghum using a novel low temperature enzyme system: Impacts of sorghum grain composition and microstructure. *Food Chemistry, [S. l.]*, v. 221, p. 324–334, 2017.

KRUGER, J. *et al.* Potential for improvement in yeast nutrition in raw whole grain sorghum and maize lager brewing and bioethanol production through grain genetic modification and phytase treatment. *Journal of the Institute of Brewing*, *[S. l.]*, v. 118, p. 70–75, 2012.

LANDAU, C. E.; SCHAFFERT, E. R. Zoneamento de áreas aptas para o plantio de sorgo sacarino na época de entressafra de cana-de-açúcar no Brasil. *Agroenergia em revista*, *[S. l.]*, n. 3, p. 20–21, 2011.

LITTLE, R.R.; Hilder, G.B.; Dawson, E.H. Differential effect of dilute alkali on 25 varieties of milled white rice. *Cereal Chemistry,* 35: 111-126, 1958.

MA, C. *et al.* Analysis of flavour compounds in beer with extruded sorghum as an adjunct using headspace solid-phase micro-extraction and gas chromatography–mass spectrometry. *Journal of the Institute of Brewing, [S. l.]*, v. 122, p. 251–260, 2016.

MAY, A. Cultivo de sorgo sacarino em áreas de reforma de canaviais. *Embrapa, Circular Técnica, [S. l.]*, v. 186, p. 36, 2013.

OGBONNA, A. C. Current Developments in Malting and Brewing Trials with Sorghum in Nigeria: A Review. *Journal of the Institute of Brewing, [S. l.]*, v. 117, n. 3, p. 394–400, 2011.

OKOLO, B. N. *et al.* Influence of malted barley and exogenous enzymes on the glucose/maltose balance of worts with sorghum or barley as an adjunct. *Journal of the Institute of Brewing, [S. l.]*, v. 126, p. 46–52, 2020.

ROONEY, L. W.; SALDIVAR, S. O. S. Sorghum. *In*: *Encyclopedia of Food Sciences and Nutrition (Second Edition). [S. l.: s. n.]*. *E-book*, 2003.

SCHNITZENBAUMER, B. *et al.* Implementation of commercial oat and sorghum flours in brewing. *Eur Food Res Technol, [S. l.]*, 2014.

SCHNITZENBAUMER, B; ARENDT, K. E.; . Brewing with up to 40% unmalted oats (Avena sativa) and sorghum (Sorghum bicolor): a review. *The Institute of Brewing & Distilling, [S. l.]*, 2014.

SALAZAR-LÓPEZ, N. J. *et al.* Technologies applied to sorghum (Sorghum bicolor L. Moench): changes in phenolic compounds and antioxidant capacity. *Food Science and Technology*, *[S. l.]*, v. 38, n. 3, p. 369–382, 2018.

TOKPOHOZIN, S. E.; FISCHER, S.; BECKER, T. Optimization of malting conditions for two landraces of West African sorghum and influence of mash bio-acidification on saccharification improvement. *Journal of Cereal Science, [S. l.]*, v. 85, p. 192–198, 2019 a.

TOKPOHOZIN, S. E.; FISCHER, S.; BECKER, T. Selection of a new *Saccharomyces yeast* to enhance relevant sorghum beer aroma components, higher alcohols and esters. *Food Microbiology, [S. l.]*, v. 83, n. May, p. 181–186, 2019 b.

VASCONCELOS, Y. Inovações Cervejeiras. *Rev Pesquisa Fapesp*, *[S. l.]*, p. 19–24, 2017.

YORKE, J.; COOK, D.; FORD, R. Brewing with Unmalted Cereal Adjuncts: Sensory and Analytical Impacts on Beer Quality. *Beverages,* vol. 7, n. 4, 2021.

ZOBEL, H. F. Chapter IX- Gelatinization of starch and mechanical properties of starch pastes. In: WHISTLER, R. L.; BEMILLER, J. N.; PASCHALL, E. F. *Starch*: Chemistry and Technology. Second Edition. Academic Press, 1984.

[1]Carolina Carla Valera Sanchez. Discente do curso Técnico em Química Integrado ao Ensino Médio. Instituto Federal de Educação, Ciência e Tecnologia – câmpus Sertãozinho, carolsanches49@gmail.com;
[2]Vitória Souza Lima. Discente do curso Técnico em Química Integrado ao Ensino Médio. Instituto Federal de Educação, Ciência e Tecnologia – Câmpus Sertãozinho, vitoriasouzalimamastz@hotmail.com;
[3]Jean Carlos Rodrigues da Silva. Professor do Instituto Federal de Educação, Ciência e Tecnologia – câmpus Sertãozinho, Biólogo, doutor em ciências, área de concentração: bioquímica. Atualmente com pesquisas na área de Tecnologia Cervejeira, jeanrodrigues@ifsp.edu.br, Link para Currículo Lattes: http://lattes.cnpq.br/6336836768530152, Telefone: (16) 98135-2397.

[1,2,3,] Instituto Federal de Educação, Ciência e Tecnologia de São Paulo, IFSP – Câmpus Sertãozinho R. Américo Ambrósio, 269 - Jardim Canaa, Sertãozinho - SP, 14169-263.

Este artigo:
Recebido em: 07/2022
Aceito em: 10/2022

Como citar este artigo:

SILVA, Jean Carlos Rodrigues da et al. Beer production using saccharine sorghum (*Sorghum bicolor*): potential and possibilities. *Scientia Vitae*, v.14, n.39, ano 9, p. 1-10, out./nov./dez. 2022.