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THE PRODUCTION OF BIOKEROSENE IN BRAZIL: THE USE OF MACAÚBA (ACROCOMIA ACULEATA) AS RAW MATERIAL IN BIOREFINERY

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Abstract: The use of fossil fuels over the years has showed a major source of contribution to environmental problems due to gas emissions, such as what contributes to the development of the greenhouse effect. The use of raw materials from biomass is seen as a solution to overcome this problem, since, from lignocellulosic materials, saccharine and starch sources and vegetable oils, it is possible to produce biofuels with characteristics that allow the replacement of fossil fuels commonly used. The production process of these bioproducts takes place in biorefineries, which are responsible for carrying out the process of converting biomass into bioproducts with a focus on sustainability and the development of new technologies. A type of biofuel that has been gaining space and attention is biokerosene, Brazil is one of the countries that consumes the most kerosene and recently a law with the aim of promoting the use and production of biokerosene in Brazilian territory. From this, this work aims to study the biokerosene production process in a biorefinery from macaúba, a biomass found on a large scale in the country, and the prospects for using this biofuel.

Keywords: Biorefineries, Macaúba, Biofuels, Biokerosene, Activated Carbon.

INTRODUCTION

The use of fuels such as gasoline, diesel and kerosene has become a global concern mainly due to two factors: the scarcity of non-renewable resources and the emission of gases that contribute to the worsening of environmental impacts (RIBEIRO; SCHIRMER, 2017). These fuels are classified as fossil fuels which, in turn, can be understood as carbon compounds originating from organic matter decomposition processes (REIS; GONÇALVES; FREITAS, 2022).

In view of the issues presented, new energy sources became the focus of study in the search to overcome the problems surrounding the energy sources that are commonly used. The implementation of the use of a raw material called biomass, for the production of fuels, has proven over the years to be a favorable solution (GUIMARÃES; COLAVITE; SILVA, 2019). With the application of physical, chemical/biological or thermal processes, it is possible to obtain biofuels and other bioproducts that provide energy generation with a reduction in observed impacts, when compared to the use of fossil fuels (LIU et al., 2021).

The development of products from renewable sources has become an important focus of research and, as a result, public policies and programs have been established around the world to expand these practices. From this, associated with the context of bioeconomy, the concept of biorefinery emerged, which has been developed and discussed by researchers in the field. In the literature there are different concepts to define what a biorefinery is, its processes and products of interest. The biorefinery can be conceptualized as a facility that integrates biomass conversion processes into biofuels, with the aim of optimizing the use of resources and minimizing effluents (EMBRAPA, 2020).

In Brazil, the use of fossil fuels has an economic strength mainly due to the oil refineries present in the country. Despite also being recognized for the use of renewable energy, the use of these resources in Brazilian territory was stagnant for a long time (FAZZI et al., 2020). It was in 2017, following Law Number: 13,576, which presented the National Biofuels Policy known as RenovaBio, that the discussion about the production of renewable energy in Brazil returned to focus with the aim of complying with the commitments determined in the Paris Agreement and promoting the adequate expansion of biofuels in the energy matrix.

The Paris Agreement approved in 2015 at COP-21, and which came into force in 2016, presents the importance of commitments from all levels of government, in accordance with national legislation, in combating climate change (REIS; GONÇALVES; SOUZA, 2017). It is a global treaty that governs measures to reduce carbon dioxide emissions from 2020 onwards. The Brazilian government has committed to reducing greenhouse gas emissions by 37% in 2025, with a subsequent indicative contribution of a 43% reduction. in 2030, in relation to the emission levels estimated for 2005 (BRAZIL, 2021). To achieve the objectives, national targets are established annually and, thus, the aim is to decarbonize the fuel sector. (BRAZIL, 2017).

Recently, in mid-2021, Law Number: 14,248 was sanctioned, establishing the National Biokerosene Program (PNB). The project aims to research and promote the production of energy based on biomass, with the aim of promoting the sustainability of Brazilian aviation. The program covers the development of technology for mixing biokerosene with aviation kerosene of fossil origin and, in addition, the development of technologies that guarantee the gradual replacement of aviation fuel of fossil origin. The prospect is that in the coming years there will be a total replacement of fossil fuels used in aircraft (BRAZIL, 2021).

There are two types of aviation kerosene that are used in Brazil: QAV-1 which is used for civil aviation and QAV-5 used in military aviation. These fuels are obtained from petroleum distillation processes, but with the implementation of biofuel production it is possible to obtain products that meet performance requirements and can be used in the aviation sector (ROCCO; HENKES, 2020).

Biomass is an energy source that contains carbon in its composition, but during its life cycle when applied in the production of biofuels, it can absorb CO2 gas from the air, emitted after burning, in its organic development process (WEI et al., 2019).

The Brazilian territory has a large availability of resources that can be used as raw materials for the production of biofuels, such as biokerosene, with each region of the country standing out in the production of a certain product (GUIMARÃES, COLAVITE; SILVA, 2019). When it comes to the production of biokerosene, it can be obtained from raw materials such as lignocellulosic biomass, saccharine sources, starch and vegetable oils. Among the cultivated oilseeds, soybeans stand out for meeting the basic and essential parameters for the sustainability of a biokerosene production program in Brazil: technological mastery, production scale and logistics of spatial distribution of the raw material in the national territory (EMBRAPA, 2015). However, there are studies that point to the use of other raw materials for the production of biokerosene in Brazil, such as macaúba, babaçu, jatropha and licuri, which are biomasses found on a large scale in the country (AQUINO et al., 2022).

There are studies that report the use of residual biomass from bioproduct production processes to obtain second-generation ethanol and activated carbon, with the aim of finding a destination for these materials that can end up contributing to pollution rates when not disposed of in a safe manner. correct. The type of bioproduct obtained from residual biomass will depend on the conversion process of this raw material and, generally, some pre-treatment processes are necessary so that this material can be applied in order to obtain better results (VIVIAN et al, 2022).

METHODOLOGY

To carry out this work, a bibliographical review was organized focusing on the biokerosene production processes in a biorefinery and the raw materials commonly used, mainly the processes that concern the use of macaúba.

MACAÚBA

The macaúba, scientifically named Acrocomia aculeata, is a species of palm tree typical of tropical regions of Latin America and is found in a large part of the Brazilian territory (RÍO et al., 2016). From the fruit of this palm tree, it is possible to extract vegetable oil that can be used in different industrial processes, such as pharmaceutical, food and energy production. This fruit has a division made up of peel (epicarp), pulp (mesocarp), tegument (endocarp) and almond (endosperm), with the pulp being the part of the fruit that has the greatest amount of available oil. (XAVIER; COSTA, 2020).

The macaúba fruit has become an alternative source option for the production of biofuels due to its high oil productivity, which is interesting when discussing the production of biodiesel and biokerosene. With industrial practices applying adequate crop management and correct fruit collection, productivity is approximately 5000 kg/ha of oil and 25 thousand kg/ha of fruit (MOTA et al., 2011). The complete production cycle of macaúba fruits takes around 12 and 14 months, and oil accumulation occurs at the end of the cycle (CÉSAR et al., 2015).

Studies report the use of oil from the mesocarp (pulp) for the production of biodiesel due to the macaúba fruit following the main objectives of the National Biodiesel Production and Use Program: the valorization of oilseed cultivation by small farmers and the diversification of materials -raw (EVARISTO et al., 2016). As well as for the production of biodiesel, the oil extracted from the pulp of the macaúba fruit can be used in the production of other bioproducts, one of which is biokerosene (SILVA et al., 2016).

The oil from the pulp is a compound that has unsaturated chains in its composition and, normally, a large amount of free fatty acids, which are compounds that present undesirable characteristics for the food and biodiesel production industries. However, when it comes to the production of biokerosene, the presence of free fatty acids in the pulp oil is not a problem, due to the commonly used production route called SPK in English. – HEFA (*Synthetic Paraffinic Kerosene – Hydroprocess of Esters Fatty Acids*) (MOREIRA; REZENDE; PASA, 2020).

BIOREFINERIES

The bioeconomy is a precursor concept, discussed around the world, for the implementation of biorefineries. It can be defined as the transition of global industry towards sustainability, with the application of renewable terrestrial and aquatic resources for energy production. It is seen as an opportunity to transform the energy market, create jobs and improve environmental performance. Biorefineries are associated with the bioeconomy as they are a way of promoting the creation of incentive programs for the consumption and production of bioproducts (COUTINHO et al., 2019).

Biomass, the raw material used by biorefineries, is the main factor that differentiates a biorefinery from a fossil fuel refinery. These resources are capable of producing bioproducts capable of helping to reduce polluting gases in the atmosphere, which is a global concern (RESTREPO-SERNA; MARTÍNEZ-RUANO; CARDONA-ALZATE, 2018). There are efforts around the world to develop technologies for the use of biomass for energy production, with emphasis on its use in the generation of fuels, thus replacing the consumption of fossil fuels in the long term (SANTOS; BORSCHIVER; COUTO, 2009).

A biorefinery integrates processes and equipment with the aim of converting biomass into energy, chemical products and biofuels (BIAZATTI; MIRANDA, 2021). It is a production process that takes into consideration, the use of a raw material capable of contributing to the reduction of CO2 emissions into the atmosphere, outlining all production stages with the objective of producing bioproducts, reducing material waste and production cost. It can therefore be defined as the sustainable processing of biomass into different marketable bioproducts (TORRES; KRAAN; DOMÍNGUEZ, 2019; GANDAM et al., 2022).

During the production stages of bioproducts in a biorefinery, the precursor material may undergo mechanical (fractionation, separation, extraction), chemical (acid or alkaline hydrolysis, delignification), thermochemical (steam explosion, enzymatic conversion) and microbial (saccharification) treatment. enzymatic, fermentation, anaerobic digestion) (PALOMO-BRIONES et al., 2018). The choice of process that will be used will depend on the type of biomass used by the biorefinery.

In Brazil, there are companies that are interested in implementing biorefineries for aviation biokerosene by the year 2024. This is the case of the company Acelen, founded in the United Arab Emirates, and which has a goal of manufacturing 1 billion liters of biofuel per year from macaúba oil (REVISTA OE, 2023).

RESULTS AND DISCUSSION

To discuss the production processes of biokerosene and also activated carbon from macaúba fruit, a flowchart was created that presents the production stages based on works present in the literature. Figure 1 shows the flowchart created.

MACAÚBA OIL EXTRACTION

The macaúba oil extraction process can provide two types of oils, pulp and almond oil. The oil levels are higher in the pulp compared to the almond (COSTA, 2016). In the flowchart proposed for the production of biokerosene, the process of extracting oil from the fruit pulp is done by pressing the fruit without the shell, separating it from the seed where the almond is present. The fruit with the skin initially passes through a peeler, goes to a pulper that separates the pulp from the stone and, subsequently, the oil from the pulp is extracted through a pressing process followed by decantation and filtration.

The oil extracted from the fruit pulp has a composition with unsaturated fatty acids, in addition, it has a high oleic acid content. The high oleic acid content is favorable from the point of view of the oil's oxidative stability and the low saturated fatty acid content provides a decrease in the crystallization tendency in relation to temperature (COSTA, 2016). The oil extraction process by pressing is recommended for raw materials with a high oil content (EMBRAPA, 2021).

In addition to using pulp oil to produce biokerosene, almond oil can also be commercialized and used in the production of soaps and other personal hygiene and food products (EMBRAPA, 2019).

Almond oil is a product obtained during the biokerosene production process that can be used to produce biofuels (SILVA et al., 2020). This material can be used for the production of biokerosene via methyl transesterification

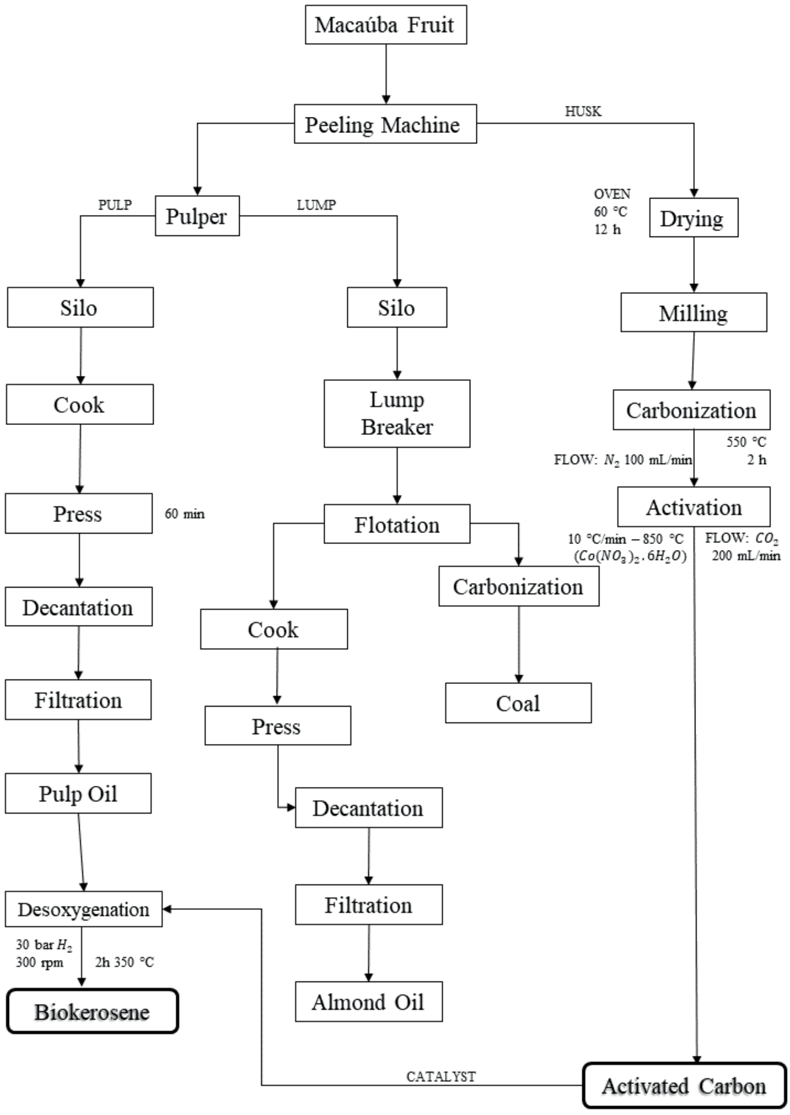

Figure 1 shows the flowchart created.

and homogeneous alkaline catalysis, followed by atmospheric distillation of the lighter esters, to then be obtained from a product that has carbon chain sizes similar to those of aviation kerosene. From this, it is possible to create mixtures to collaborate in the process of reducing the emission of gases that affect the environment (HARTER; SANTOS; FABRIS, 2019).

SPK – HEFA (*SYNTHETIC PARAFFINIC KEROSENE – HYDROPROCESS OF ESTERS FATTY ACIDS)*

The production of biokerosene is based on the technique called SPK – HEFA, in which the deoxygenation of triglycerides occurs under conditions of temperature between 250 and 450 °C and hydrogen pressure between 10 and 300 bar in the presence of specific catalysts. After this step, isomerization is carried out to adjust the carbon chains into the desired hydrocarbon fractions, thus resulting in biokerosene that can be mixed up to 50% with aviation kerosene (AQUINO et al., 2022) (STARCK et al, 2016). According to the work of MOREIRA et al. 2020, the deoxygenation process for the production of biokerosene can be carried out at a pressure of 30 bar, with H_2, at a temperature of 350 °C, at 300 rpm.

The pulp oil deoxygenation process is important, since the presence of oxygenated groups in its composition reduces its compatibility with conventional engines (SILVA et al., 2021). It can occur through three distinct routes: decarboxylation, decarbonylation and hydrogenation/ dehydration. In the literature, the last route previously mentioned can also be called hydrodeoxygenation (JÚNIOR, 2015).

The catalyst used during the macaúba pulp oil deoxygenation process can be a sulfide metal, noble metals (Pt, Pd and Ru), other metals such as Ni and Co and bimetallic catalysts, used with zeolites, alumina and coal support. activated (MOREIRA et al., 2020). Moreira et al., present a methodology in which activated carbon produced from the fruit peel is impregnated with cobalt using cobalt (II) nitrate hexahydrate (〚Co (NO〛_3)_2.6H_2 O) and then applied during biofuel production. The production cost and technological aspects of the process are examples of factors that are considered important during the biofuel production process (TEIXEIRA, 2013).

ACTIVATED CHARCOAL

Activated carbon is a porous material used as an adsorbent and catalyst support during removal and purification reactions (GAYATHIRI et al., 2022). The production of activated carbon from residual lignocellulosic biomass is presented in the flowchart. After the macaúba fruit peeling process, the peels undergo a drying process in an oven at 60 °C for 12 hours (ZANATTA, 2015). This step is important for the volatilization of compounds such as water from the structure of the material that will be used in the production of activated carbon (SCHETTINO et al., 2007). Next, the material goes through a grinding process in which the particle size of the material is adjusted according to its subsequent application.

According to Moreira et al., 2020, the raw material carbonization process is carried out in an oven at 550 ° C, for 2 hours and in a nitrogen flow at a rate of 100 mL/min. Next, the carbonization process is carried out with a 〚CO〛_2 flow at a rate of 200 mL/min, with a variation of 10 °C/min until a temperature of 850 °C is reached. Due to the fact that the material will later be used as a support for a catalyst in the deoxygenation stage, during the biokerosene production process, the activated carbon surface is impregnated with cobalt (II) nitrate hexahydrate.

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CONCLUSION

According to works found in the literature, the production of biokerosene from macaúba fruit pulp oil is a viable production route for a biorefinery. In addition to the high production of vegetable oil, macaúba is a species of plant found in several regions of the Brazilian territory, which contributes to the development of practices such as the production of biofuels in Brazil. The potential to become one of the largest biofuels producing countries exists and, based on this, studies can be carried out to develop new production techniques that support the development of ecologically sustainable practices. From this, it is expected that in the coming years new biokerosene biorefineries will be implemented in Brazil and that fossil aviation fuels will be replaced by biofuels produced from biomass found on Brazilian soil and that, as a result, the emission of gases from greenhouse effect effectively decrease.

REFERENCES

AQUINO, A. S. et al. **Mapping of Alternative Oilseeds from the Brazilian Caatinga and Assessment of Catalytic Pathways towards Biofuels Production.** Energies, v. 15, p. 1-25, 2022.

BIAZATTI, M. J.; MIRANDA, J. C. C. **Soybean-based concept biorefinery.** Biofuels, Bioproducts, Biorefining, v. 15, p. 980-1005, 2021.

BRASIL. **Lei n° 13.576, de 26 de dezembro de 2017**. Brasília, DF, 26 de dezembro de 2017.

BRASIL. **Lei n° 14.248, de 25 de novembro de 2021**. Brasília, DF, 25 de novembro de 2021, Seção 1, p. 3.

CÉSAR, A. S. et al. **The prospects of using Acrocomia aculeata (macaúba) a non-edible biodiesel feedstock in Brazil.** Renewable and Sustainable Energy Reviews, v. 49, p. 1213-1220, 2015.

COSTA, D. A. N. **Estudo do processo de extração do óleo da macaúba (Acrocomia intumescens).** 2016. Maceió: Dissertação (Mestrado em Engenharia Química) – Universidade Federal de Alagoas.

COUTINHO, P. L. A. et al. **Intensificação de processos e química verde: importância para as indústrias farmacêutica, cosméticos, alimentícia e biorrefinarias.** Fitos, v. 13, p. 2446-4775, 2019.

EMBRAPA. **Biorrefinarias**. 2011. Disponível em:https://ainfo.cnptia.embrapa.br/digital/bitstream/item/48750/1/biorrefinaria-modificado-web.pdf . Acesso em: maio, 2023.

EMBRAPA. **Matérias-primas oleaginosas para a produção de bioquerosene – oportunidades e desafios.** 2015. Disponível em: https://www.embrapa.br/busca-de-noticias/-/noticia/3344909/artigo-materias-primas-oleaginosas-para-a-producao-de-bioquerosene--oportunidades-e-desafios. Acesso em: maio, 2023.

EMBRAPA. **Brasil e Paraguai fazem parceria para extrair óleo de macaúba com alta qualidade.** 2019. Disponível em: https://www.embrapa.br/busca-de-noticias/-/noticia/40989603/brasil-e-paraguai-fazem-parceria-para-extrair-oleo-de-macauba-com-alta-qualidade. Acesso em: junho, 2023.

EMBRAPA. **Processamento.** 2020. Disponível em: https://www.embrapa.br/agencia-de-informacao-tecnologica/tematicas/tecnologia-de-alimentos/processos/grupos-de-alimentos/oleaginosas/processamento#:~:text=O%20processo%20de%20extra%C3%A7%C3%A3o%20de%20%C3%B3leos%20em%20escala,palma%20e%20am%C3%AAndoas%20com%20alto%20teor%20de%20%C3%B3leo. Acesso em: junho, 2023.

EVARISTO, A. B. et al. **Actual and putative potentials of macaúba palm as feedstock for solid biofuel production from residues.** Biomass and Bioenergy, v. 85, p. 18-24, 2016.

FAZZI, L. R. et al. **A Regulação de biocombustíveis no Brasil e nos EUA no contexto da mitigação das mudanças climáticas e do correlato Acordo de Paris.** Revista Gestão & Sustentabilidade Ambiental, v. 9, p. 104-119, 2020.

GANDAM, P. K. et al. **Corncob-based biorefinery: A comprehensive review of pretreatment methodologies, and biorefinery platforms.** Journal of the Energy Institute, v. 101, p. 290-308, 2022.

GAYATHIRI, M. et al. **Activated carbon from biomass waste precursors: Factors affecting production and adsorption mechanism**. Chemosphere, v. 294, p. 1-12, 2022.

GUIMARÃES, A. F.; COLAVITE, A. P.; SILVA, E. A. **A rede de produção de biocombustíveis da região sul do Brasil.** Revista de Geografia, v. 36, p. 63-82, 2019.

HARTER, L. V. L.; SANTOS, D. Q.; FABRIS, J. D. **Destilação atmosférica do biodiesel derivado do óleo de macaúba ou do palmiste para obtenção da fração de ésteres leves para uso como combustível de aviação.** Química Nova, v. 42, p. 143-148, 2019.

JÚNIOR, A. M. F. **Reações de hidrodesoxigenação aplicadas à produção de biocombustíveis parafínicos de cadeia longa a partir de óleos e gorduras.** 2015. Brasília: Dissertação (Mestrado em Tecnologias Química e Biológica) – Universidade de Brasília.

LIU, Y. et al. **Biofuels for a sustainable future.** Cell, v. 184, p. 1636-1647, 2021.

MOREIRA, J. B. D.; REZENDE, D. B.; PASA, V. M. D. **Deoxygenation of Macauba acid oil over Co-based supported on activated biochar from Macauba endocarp: A potential and sustainable route for green diesel and biokerosene production.** Fuel, v. 269, p. 1-12, 2020.

MOTA, C. S. et al. **Exploração sustentável da macaúba para produção de biodiesel: colheita, pós-colheita e qualidade dos frutos.** Informe Agropecuário, v. 32, p. 41-51, 2011.

PALOMO-BRIONES, R. et al. **Agave bagasse biorefinery: processing and perspectives.** Clean Technologies and Environmental Policy, v. 20, p. 1423-1441, 2018.

REIS, M. C.; GOLÇALVES, W.; FREITAS, R. R. **Evolutionary Overview of Biofuels Productivity in Brazil in the Last 10 Years.** Brazilian Journal of Production Engineering, v. 8, p. 34-46, 2022.

RESTREPO-SENA, D. L.; MATÍNEZ-RUANO, J. A.; CARDONA-ALZATE, C. A. **Energy efficiency of biorefinery schemes using sugarcane bagasse as raw material.** Energies, v. 11, p. 1-12, 2018.

REVISTA OE. **Acelen inicia biorrefinaria em janeiro 2024.** 2023. Disponível em: https://revistaoe.com.br/acelen-inicia-biorrefinaria-em-janeiro-2024/. Acesso em: junho, 2023.

RIBEIRO, C. B.; SCHIRMER, W. N. **Panorama dos combustíveis e biocombustíveis no Brasil e as emissões gasosas decorrentes do uso da gasolina/etanol.** Biofix Scientific Journal, v. 2, p. 16-22, 2017.

RÍO, J. C. et al. **Chemical composition and termal behavior of the pulp and kernel oils from macaúba palm (Acrocomia aculeata) fruit.** Industrial Crops and Products, v. 84, p. 294-304, 2016.

ROCCO, G. K.; KENKES, J. A. **Biocombustíveis sustentáveis para a aviação no Brasil.** Revista Gestão & Sustentabilidade Ambiental, v. 9, p. 191-226, 2020.

SACHS, I.; MAIMOM, D.; TOLMASQUIM, M. T. **The Social and Ecological Impacto f 'Pro-Alcool'.** IDS Bulletim, v. 18, 39-45, 1986.

SANTOS, M. F. R. F.; BORSCHIVER, S.; COUTO, M. A. P. G. **Monitoring technology on biorefineries from sources of renewable raw material.** Pensamento Contemporâneo em Administração, v. 3, p. 21-29, 2009.

SCHETTINO, M. A. et al. **Preparação e caracterização de carvão ativado quimicamente a partir da casca de arroz.** Química Nova, v. 30, p. 1663-1668, 2007.

SILVA, L. N. et al. **Biokerosene and green diesel from macauba oils via catalytic deoxygenation over Pd/C.** Fuel, v. 164, p. 329-338, 2016.

SILVA, M. S. B. et al. **Reações de descarbonilação de ácidos graxos mediadas por catálise metálica homogênea: Um método alternativo para a produção de alcenos de origem renovável.** In: CONEPETRO – Congresso Nacional de Engenharia de Petróleo, Gás Natural e Biocombustíveis, IV, 2021.

STARCK, L. et al. **Production of Hydroprocessed Esters and Fatty Acids (HEFA) – Optimisation of Process Yield**. IFP Energies Nouvelles, v. 71, p. 1-13, 2016.

STATTMAN, S. L.; HOSPES, O.; MOL, A. P. J. **Governing biofuels in Brazil: A comparison of etanol and biodiesel policies.** Energy Policy, v. 61, p. 22-30, 2013.

TEIXEIRA, A. R. F. A. **Revisão da Literatura: Desoxigenação catalítica de ácidos graxos e derivados – Síntese de bio-óleo.** 2013. João Pessoa: Monografia (Graduação em Química) – Universidade Federal da Paraíba.

TORRES, M. D.; KRAAN, S.; DOMÍNGUES, H. **Seaweed biorefinery.** Reviews in Enviromental Science and Biotechnology, v. 18, p. 335-388, 2019.

VIVIAN, M. A. et al. **Caracterization of sugarcane bagasse and its potential for energy generation and cellulosic pulp.** Madera y Bosques, v. 28, p. 1-11, 2022.

WEI, H. et al. **Renewable bio-jet fuel production for aviation: A review.** Fuel, v. 254, p. 1-16, 2019.

XAVIER, E. V. A.; COSTA, A. A. **Aplicações da Macaúba: um estudo prospectivo.** Cadernos de Prospecção, v. 13, p. 1147-1163, 2020.

ZANATTA, S. **Caracterização da macaúba (casca, polpa e amêndoa) e análise sensorial através da Educação do Gosto.** 2015. Piracicaba: Dissertação (Mestrado em Ciências) – Universidade de São Paulo.