THE USAGE OF THE ACAI STONE AS REINFORCEMENT FOR THE MODELING OF PLANT POLYURETHANE MATRIX COMPOSITE MATERIAL

O USO DO CAROÇO DO AÇAÍ COMO REFORÇO PARA A MODELAGEM DE MATERIAL COMPÓSITO DE MATRIZ DE POLIURETANO VEGETAL

BRENNA PAULA BOAVENTURA CORRÊA CAVALCANTI, M.Sc. | UFAM
GERALDO LIRA DE SOUZA, M.Sc. | UFAM
ACURSIO YPIRANGA BENEVIDES JÚNIOR, M.Sc. | UFAM
CLAUDETE BARBOSA RUSCHIVAL, Dra. | UFAM
MAGNÓLIA GRANGEIRO QUIRINO, Dra. | UFAM
DANIEL FERREIRA DE CASTRO, Dr. | UFAM

RESUMO
Na região norte do Brasil a fruta açaí é um produto típico e muito consumido por suas qualidades nutritivas e medicinais, ocupando importante papel socioeconômico no país. Os resíduos gerados após a extração da polpa da fruta correspondem a 85% do volume produzido, montante que é descartado em lixões a céu aberto sem um planejamento adequado. O trabalho apresenta um estudo inicial do aproveitamento do caroço do açaí usado como reforço para confeccionar material compósito de matriz em resina biodegradável a base do óleo de mamona. A base metodológica para a realização do estudo foi a pesquisa bibliográfica para associar conhecimentos sobre o fruto açaí e seus resíduos, e materiais compósitos com reforço de fibras naturais. Para o desenvolvimento do novo material foi utilizada a pesquisa de Quirino (2010) como referência para a moldagem do painel e para a realização do ensaios de densidade, bem como a norma ABNT NBR 14810-1 (2013). Os resultados demonstram que o processo utilizado para a produção do painel compósito resulta em material de alta densidade, apresentando ainda diferencial estético e qualidade visual. A contribuição do estudo está no aproveitamento de recursos naturais para a minimização dos impactos ambientais negativos resultantes do ciclo produtivo do açaí.

PALAVRAS CHAVE: Resíduos do açaí; material compósito; inovação

ABSTRACT
In the north region of Brazil the acai fruit is a typical product that is widely consumed for its nutritional and medicinal qualities, occupying an important socioeconomic role in the country. The residues generated after the extraction of the fruit pulp correspond to 85% of the volume produced, an amount that is discarded in open dumps without adequate planning. The paper presents an initial study of the use of the acai stone used as reinforcement to make a composite matrix material in biodegradable resin based on castor oil. The methodological basis for the study was the bibliographical research to associate knowledge about the acai fruit and its residues, and composite materials reinforced with natural fibers. For the development of the new material we used the research Quirino (2010) as a reference for panel molding and for conducting density tests as well as the standard ABNT NBR 14810-1 (2013). The results demonstrate that the process used to produce the composite panel results in high density material, also showing an aesthetic differential and visual quality. The contribution of the study is in the use of natural resources to minimize the negative environmental impacts resulting from the production cycle of acai.

KEY WORDS: *Acai waste; composite material; innovation*

http://dx.doi.org/10.29183/2447-3073.MIX2021.v7.n3.19-28
ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)

1. INTRODUCTION

Alternatives for the use of residual materials, traditionally considered as process rejects, arise when the manufacturing and industrialization techniques find dialogs in the scientific base for practical answers to technical problems. This type of activity, in contemporary terms, is considered as an aspect for innovation and technological development.

Innovation occurs when an organizational product, method or process is first inserted in the market and generates an economic impact, for those responsible for its insertion (OCDE, 1997). However, despite the relevance of processes and organizational models that generate significant economic impacts on the productive sector, product and process innovations are still the deepest in the development, science and technology sector.

Regarding product and process innovations, the academic environment is very influential when it proposes alternatives for recycling or reusing discarded products after use, or for waste generated during industrial manufacturing processes, promoting economic impact on productivity or added value to the market and final consumers. To make the process more productive or to boost other processes, using residues that are naturally particular to them, converging benefits strategically, approaching processes competing for common or correlated ends, are typical postures of competitive environments in the various sectors of such as trade and services, agriculture and industry.

It is in this area - productive spaces that generate income and employment - that the academic-scientific area meets demands that make it indispensable in the confrontation of problems and in the search for innovative solutions, with advances of quality and growth linked to the generation of value.

Companies in the industrial sector have the basic commitment to maintain corporate objectives and comply with public standards such as security, environment and other conformities necessary to maintain licit business practices. One of these practices is the correct destination of waste from its production processes, in which solutions such as the development of composite materials are discussed.

In this case, the residues are used as a filler element for the matrices of materials such as polymers, based on polyol - a type of ethyl -, ceramics or metals, promoting cycles of strategic use, with positive economic as well as with security and environment standards. This paper corresponds to yet another technical, academic and scientific action in search of new forms of waste recovery resulting from productive processes.

Acai is a product typical of the Northern region of Brazil and is much questioned in academia and in the technology centers, on the multiple possibilities of the use of the residues coming from its beneficiation process. This is because acai is consumed not only throughout Brazil but also abroad, and its exploitation is not restricted to a region, which consequently brings up the issue of what to do with the process waste.

A study carried out by Almeida et al. (2017) shows that only 15% of the production is of the wine resulting from the processing of fruit pulp, and that the rejects correspond to 85% of the stone and fibers that are inappropriately discarded in nature or in public places and spaces.

The literature presents several alternatives for the use of these wastes, such as biofuels for energy generation (SILVA et al., 2004; XAVIER et al., 2006); such as organic compost, briquettes, handicrafts and animal feed (SANTOS; SANTOS; SENA, 2018); feed, fertilizer and charcoal (FREIRE, 2018); and organic compost (DIAS et al., 2016). The possibility conjectured for this study is the use of the acai seed as reinforcement to compose the element that gives filling to new composite materials, as revealed by Mei and Oliveira (2017), that sees a lot of potential in the natural fibers to act like a filler in polymeric composites.

This study aims to answer whether the acai seed, a typical surplus of the fruit processing process, can serve as a filler for the castor-based vegetable polyurethane matrix. The aim is to develop a composite material for application in product design for the trade and services sectors, with environmental sustainability as an added value.

As seen, there are several purposes given to the acai seed, such as an application in the handicrafts, in the production of electric energy, mechanics and gas and fuel for boilers. There remains a proposal to present it as a basis for composite, an innovative possibility in the use of this rich Brazilian raw material.

With this purpose, we performed: (i) a review of the literature to obtain information about work already done with residues from the processing of acai fruit; (ii) a theoretical survey to know the characteristics and properties of composite materials; (iii) propose new composite material with acai seed loading and castor-based biopolymer matrix; and finally; (iv) perform assays to test the technical feasibility of the composite and then apply it in product design. Such actions are understood as specific objectives of this article.

2. THEORETICAL BACKGROUND

This is presented in two parts; the first is the methodological structure chosen for the theoretical reference, and the second; is linked to the theoretical bases for the three key words that guide the work, respectively, composite, polyol and acai. This is because a composite with a biodegradable binder can generate a product with a lower environmental impact, considering the environmental norms and rights, by the natural structure of the elements that compose it

2.1. Methodological framework of the theoretical references

The theoretical revision is based on a systematic review of scientific databases, with access provided by the Coordination for the Improvement of Higher Education Personnel - CAPES. The chosen database was the Scopus platform, because it contains references of scientific journals of industrial materials, the area of this paper. The intention is to use a methodological approach to deepen the theoretical reference of the research and its keywords.

Besides the keywords that directed the search of the articles, it was also decided to limit the search by year and area of publication, in a way that would allow to find articles linked to the objectives here exposed. In order to maintain the contemporaneousness of the scientific approach, it was decided to limit work to the areas mentioned: industrial materials, chemistry, engineering, chemical engineering and agriculture.

In total, twenty-five articles were found that had thematic approaches, which allowed to identify ways and concepts for the accomplishment of the work. However, only seven of these articles were scientifically harmonized with the proposed objectives. It is emphasized that the option with this type of research, limited to years and areas, is a simple initial technique to converge current and, to a certain extent, harmonic thoughts on the positions and tendencies of the scientific community.

Other sources have also been consulted because they are classic or because they have a direct connection with the proposal or linked to news channels, websites, social communication networks of government entities and research.

For the latter types of materials, the year and area of study, with thematic and scientific cohesion directly related to the objectives proposed here, were disregarded, since it is evident that much information, notwithstanding its documentary nature and its historical and fateful value, do not reach the scientific channels because they are often triggered only when the fact or the news enters the world of researchers.

The next item deals with the findings in the literature that supported this work.

2.2. Composites and the acai fruit

The composites are formed in general by reactive joining of at least two components of distinct physical and chemical properties in their composition (MEDEIROS et al., 2016; MARINHO et al., 2013). One component of the composite material is considered as a matrix, and the other as a filler.

A current trend is the use of chemical raw material based on vegetable oil, which involves the valorization of natural polyol oils (RAQUEZ et al., 2010), which contains hydroxyl groups in the chemical structure as in the case of castor oil, or by insertion of hydroxyl groups on the double bonds of unsaturated oils (COSTA et al., 2017). Due to these issues, there is much debate about the use of castor-based polyol for biodegradable composites, which are formed by loading naturally occurring substances such as acai seed and fiber.

The acai fruit comes from a palm tree typical of the tropical climate Amazon, found in the region of the estuary of the Amazon River, area of greater concentration of this palm tree (QUIRINO, 2010). It is from the bunch of acai that the acai fruit is removed (Figure 1). The removal process is still done manually. They are usually cooperatives of harvesters and growers that go up to the top of the palm tree to remove the bunch of fruit.

Figure 1: Acai Fruit.
Source: Quirino (2010).

Between 2015 and 2016, the national acai agricultural production of 1.0 million tons increased to 1.1 million (PERET, 2017), demonstrating a growing use of raw materials in the Northern Region of Brazil, mainly in the state of Pará.

Considering this production, it is becomes important to consider processing the waste material. As the studies by Quirino show that the acai seed fiber is a viable eco product for composite filling (QUIRINO, 2010).

Considering the initial concepts about the object of this work, the next step is of materials and methods, which presents the methodological process performed for the manufacture of the composite.

3. MATERIALS AND METHODS

The waste collection for the study was carried out in the city of Manaus, state of Amazonas, specifically in the Zumbi dos Palmares I neighborhood, where a popular market for agricultural products is held. This market sells various products such as fish, slaughtered poultry, beef and pork, vegetables, legumes and stews in general, as well as the acai fruit that is processed still in natura at the time of purchase by the consumer, or to be distributed and marketed in various parts of the city of Manaus.

According to information from a person responsible for the sale of acai at the market, after the fruit is processed in the machine for the extraction of the pulp or wine, the residues of that process (stones) are discarded in the garbage dump of the market and later it is collected by the municipal garbage collection car and taken to the municipal landfill.

In conversation with the stall owner at the market, it was highlighted that on average 3 bags of the composite 60 kg are processed on normal days of the week, which can triple on weekends and holidays. A bag of the composite 60 kg of this material, which was destined to the dumpster, was donated for this research (Figure 2).

With the raw material, the experiment was started to obtain the composite, which was carried out in two stages: (I) Processing of the acai stone; (II) Composite manufacture.

Figure 2: Daily acai fruit processing waste.
Source: Authors (2018).

In stage I the acai seeds were washed in a container with running water for removal of the impurities, such the remains of stalks and pulp. After the washing, the residues were placed in a plastic tarp to dry for 168 hours, which corresponds to seven days at room temperature, as recommended in the studies (QUIRINO, 2010).

In a period of 168 hours the residues were turned twice a day so to dry evenly. After drying, the core was ground. Of the 60 kg of acai seeds, only 7 kg were used for this experiment.

The next step was sieving the milled residue in a sieve with a 2 mm mesh opening for separating the granules. The useful amount of material after sieving was 5.3 kg, weighed in a precision scale (Notebook Series Digital Escale 2.000). This was packed in a paper bag (pulp) in an amount of 2 bags of 1,300 g each.

In step II of the manufacture of the composite 1,300 g of raw material of the ground acai stone was used, and as binders 98.2 g of castor-based polyol and 97.9 g of prepolymer. The mixture of the resins and the raw material was performed manually over a period of 10 minutes to obtain a homogeneous mass ready to be molded (Figure 3).

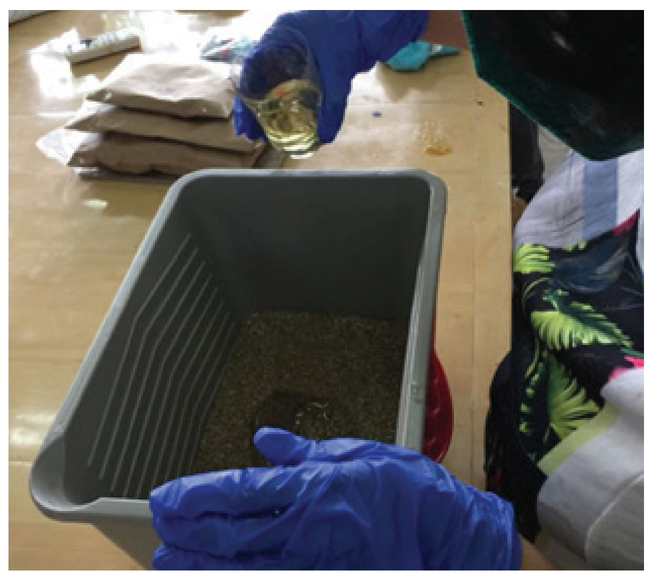

Figure 3: Manual blending of castor bean resin with the granules of the ground acai stone.
Source: Authors (2018).

The mixture was inserted into a wood mold with a metal base (40 cm x 40 cm), previously prepared with a release agent and coated with a sheet of non-stick paper. The material was compacted manually for stabilization, making it more stable (Figure 4).

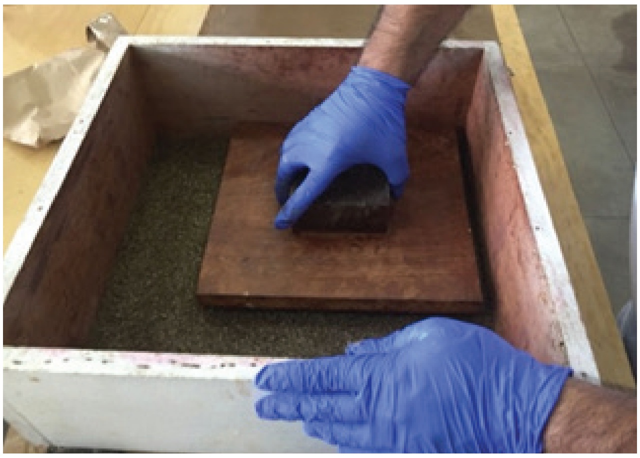

Figure 4: Manual pre-compression for compliance.
Source: Authors (2018).

After removal of the wooden mold, the molding of the composite was done to obtain a reduced block. A thermal hydraulic press (HM Hydral - Mac 2951) with a power of 19.5 Kw, voltage 220v 60 Hz 67.2 A was used in the compression, at a temperature of 100°C and a pressure of 15 MPa for 10 minutes.

After the process, a 40 cm x 40 cm panel was obtained (Figure 5) with a thickness of 9.5 mm, with a loss of 5% of material, which probably occurred during preparation due to manual manipulation.

Figure 5: Panel of the Composite obtained.
Source: Authors (2018).

The composite underwent a stabilization period of 72 hours, which is the minimum time recommended by the standard (ABNT NBR 14810-1, 2013). At the end of the curing period, the shavings were removed, and the specimens were cut for the conducting of physical tests.

3.1. Physical test: density of the panel

Twelve 25 mm x 25 mm specimens were cut to perform the density test. The equipment used in this experiment were: Analog Security pachymeter, with resolution of 0.1 mm and electronic scale Notebook series digital scale 2.000. The specimens were numbered for identification of the samples (Figure 6).

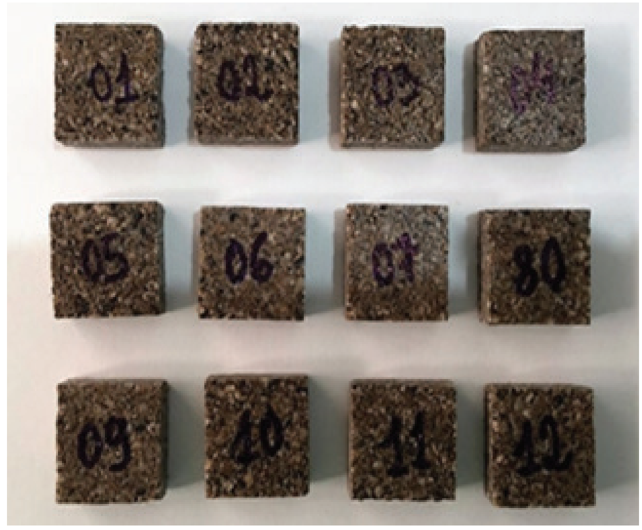

Figure 6: Test specimens for the density test, 25 mm x 25 mm.
Source: Authors (2018).

The dimensions of the specimens were measured at three points in the material sample (Figure 7), one in the center and two at the ends, proceeding in the same way to determine the length and width (QUIRINO, 2010).

Figure 7: Measurement of thickness at the center of the sample.
Source: Authors (2018).

There was no variation of measurements in the 12 specimens, with equal dimensions of 25 mm in length, 25 mm in width and 9.5 mm in thickness.

After weighing the specimens, their densities were calculated, determined by equation (ABNT NBR 14810-1, 2013):

$$D = (M/V) \times 1{,}000{,}000 \quad (1)$$

Where:

$$V = L \times C \times E \quad (2)$$

Where: D is the density of the specimen (kg/m³), M is the mass of the specimen, (g), V is the volume of the specimen, (mm³), L is the width of the specimen (mm), C is the length of the specimen, (mm), and E is the thickness of the specimen (mm). The calculations performed on the test specimens were organized in a table to better assimilate the information generated by the experimental data.

4. RESULTS

From the measurement of the 12 test specimens the density test was carried out, in order to verify in which level of density (if low, medium, high), the sample was fitted according to the reference standard used.

4.1. Density test results

The technical standard that guided the procedure was ABNT NBR 14810-1 (2013), which deals with panels of medium density particles.

With the procedures to define if the composite has a medium density index, it could be logically identified that the density can be considered high when the result is higher than indicated by the standard. Or even considered low if it does not reach the minimum indicated by the technical standard.

The results of this test are shown in Table 1.

Specimen	Volume (mm³)	Mass (g)	Density (g/mm³)	Density (kg/m³)
1	5,937.50	5.9	0.00099	993.68
2	5,937.50	5.7	0.00096	960.00
3	5,937.50	5.8	0.00098	976.84
4	5,937.50	6.3	0.00106	1,061.05
5	5,937.50	5.8	0.00098	976.84
6	5,937.50	6.2	0.00104	1,044.21
7	5,937.50	6.1	0.00103	1,027.37
8	5,937.50	6.3	0.00106	1,061.05
9	5,937.50	6.1	0.00103	1,027.37
10	5,937.50	6.2	0.00104	1,044.21
11	5,937.50	6.5	0.00109	1,094.74
12	5,937.50	6	0.00101	1,010.53

Table 1: Result of the composite panel density test.
Source: Authors (2018).

As shown in the table, the results show variability in both the mass index and the density index, according to the values obtained in the test specimens.

From the density (kg/m³), the median and the standard deviation were calculated with results respectively: 1,027.37 and standard deviation of 40.70. It is evidenced, then, that the process used to produce the composite panel results in high density material, since standard ABNT NBR 14810-1 (2013) indicates that medium density plates have an index between 551 kg/m³ and 750 kg/m³.

However, when observing the standard deviation, it was verified that the productive process used resulted in material with great variability of density, with values between 960.00 kg/m³ 1,094.74 kg/m³. Even so, it can still be considered a high-density material because it presents values above the minimum mentioned by the standard.

After the technical verification of the composite, a free verification was made of the aesthetic qualities of the composite for possible application in design products, exposed in the next topic.

4.2. Result of free aesthetic application

The properties of the resulting material are like the original components. The color, shine texture and smell do not change in the process. The visual and aestetic characteristics allow to visually distinguish the material and use it for various objects.

In order to evaluate the aesthetic relation of the new material with other products, the finish was used in natura and aesthetic-formal qualities such as color and texture. An object holder was defined as a product for this experiment, as shown in Figure 8. The composite is visually characterized by a set of shades in earth tones that look similar to that of cork. This product can also receive some types of finishes such as waxing, varnishing, coating with various films (e.g., PVC).

Figure 8: Perspective view of object holder.
Source: Authors (2018).

It also has a homogeneous appearance, with regular edges and straight angles free of burrs, defects or peeling. The natural color of the material, with light and dark nuances, results in a texture with a different visual pattern, and can be applied for various purposes, such as coatings for interior finishes in buildings, furniture and decoration products, like covering of furniture fo and interior architecture applications. The material does not have a smell.

Since the content is not dissociated from its form (Dondis, 2007), the aesthetic meaning and the perceived value of the material offer some reflections about the experiment:

a) the shape of the product, offers guidelines for studying and creating shapes that are more appropriate to the different types of consumer products, as in the case of interior design products that express meanings for the composition and decoration of environments;

b) when working with a regional product, even if in the form of waste, açaí brings a meaning of identity linked to culture and nature. It involves the consumption habit and traditional production processes. The composite material from these residues, carries perceptual values and configurations linked to local cultural manifestations.

Therefore, the cultural and social values intrinsic to the material also function as elements of beauty and differentiation for the potential final consumer.

5. CONCLUSIONS

In a methodological perspective, the study demonstrated the feasibility of the use of the acai fruit stone as reinforcement for the manufacture of composite material, whose polymeric matrix used in the mixture comes from castor oil. As a result of this mixture, a high-density material with values of 960.00 kg/m^3 and 1,094.74 kg/m^3 was obtained, being initially characterized as a biocomposite because it consists of phases of natural origin. It also has the potential to replace the consumption of various synthetic materials, such as plastics and derivatives.

The resulting composite panel is also a possible alternative to give a useful destination to the acai processing waste, offering timely ways to recover and solve the inadequate waste disposal in compliance with the environmental norms of the productive sectors, and opportunity as a source of revenue.

Although the results of this first composite study are considered positive, other assays and tests should be performed, such as the moisture content test to evaluate the variations and resistance of the material under conditions of use. Further tests are also required, such as straightness, traction and screw pulling to identify the possibilities of using the composite in the furniture and building industry as well as in the field of interior design.

It is finally hoped to stimulate the study and research in the area of materials and, where possible, focused on the diffuse rights of future generations, such as the right to a balanced environment and new perspectives on the possibilities of applying wealth for the good of all and the development of Brazilian scientific culture.

ACKNOWLEDGMENT

FAPEAM - Fundação de Amparo à Pesquisa do estado do Amazonas.

REFERENCES

ALMEIDA, A. V. DA C. et al. Revalorização do caroço de açaí em uma beneficiadora de polpas do município de Ananindeua/PA: propostade estruturação de um canal reverso orientado pela PNRS e logística reserva. GEPROS. **Gestão da Produção, Operações e Sistema,** v. 3, p. 59–83, 2017.

COSTA, A. P. O. et al. Synthesis and characterization of composites of polyuthanes obtained with soybean polyol/TDI/ minerals fillers. **Revista Virtual de Química,** v. 9, n. 4, p. 1434–1448, 2017.

DIAS, R. DA S. et al. **Aproveitamento dos resíduos gerados no despolpamento do açaí (Euterpe spp) na compostagem.** Manaus: Anais do SICASA e ANPPAS Amazônia, 2016. Disponível em: <www.even3.com.br/Anais/IVSICASA/33228-APROVEITAMENTO-DOS-RESIDUOS-GERADOS-NO-DESPOLPAMENTO-DO-ACAI-(EUTERPE-OLERACEA-MART)-NA-COMPOSTAGEM>

DONDIS, A. D. **Sintaxe da Linguagem Visual;** tradução Jefferson Luiz de Camargo. 3ª. Edição. São Paulo: Martins Fontes, 2007.

ODCE. **Manual de Oslo: Diretrizes para Coleta e Interpretação de dados sobre Inovação.** ODCE, Eurostatat e Financiadora de Estudos e Projetos, 1997.

FREIRE, R. **Projeto prevê o aproveitamento de resíduos do açaí e palmito.** Pará: Secretaria de Estado de Ciência, Tecnologia e Educação Profissional e Ciência, 2018. Disponível em: <http://www.sectet.pa.gov.br/secti/node/1881>. Acesso em: 12 jul. 2018.

MARINHO, N. P. et al. Physical and thermal characterization of polyurethane based on castor oil composite with bamboo particles. **Polímeros**, v. 23, n. 2, p. 201–205, 2013.

MEDEIROS, D. L. et al. Life cycle of plant fiber composites: a qualitative analysisof greenhouse gases (GHG) emissions of polypropylene composite with sisal fiber. **Revista Virtual de Química**, v. 8, p. 1166–1180, 2016.

MEI, L. H.; OLIVEIRA, N. Caracterização de um compósito polimérico biodegradável utilizando Poli (ε-caprolactona) e borra de café. **Polímeros**, v. Número Esp, p. 99–109, 2017.

PERET, E. **Safra de açaí foi de 1,1 milhão de toneladas em 2016.** Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro: 2017. Disponível em: <https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/16821-safra-de-acai-foi-de--1-1-milhao-de-toneladas-em-2016#:~:text=Segundo a Pesquisa Agrícola Municipal,açaí no âmbito da agricultura.>. Acesso em: 12 jul. 2018.

QUIRINO, M. G. **Estudo de matriz polimérica produzida com resina natural e fibra da semente de açaí (Euterpe precatória).** Manaus: Universidade Federal do Amazonas, 2010.

RAQUEZ, J.-M. et al. Thermosetting (bio) materials derived from renewable resources: a critical review. **Progress in Polymer Science,** v. 35, n. 4, p. 487–509, 2010.

SANTOS, G. DA S.; SANTOS, C. DA C. S.; SENA, C. DA C. **Descarte e reaproveitamento dos caroços de açaí das batedeiras do município de Laranjal do Jari - AP: uma solução possívelCongresso Sul-Americano de Resíduos Sólidos e Sustentabilidade - CONRESOL.** Gramado: Instituto Brasileiro de Estudos Ambientais - IBEAS, 2018. Disponível em: <http://www.ibeas.org.br/conresol/conresol2018/IV-064.pdf>

SILVA, I. T. DA et al. **Uso o caroço de açaí como possibilidade de desenvolvimento sustentável do meio rural, da agricultura familiar e de eletrificação rural no estado do Pará.** Campinas: AGRENER, 2004. Disponível em: <http://seeds.usp.br/pir/arquivos/congressos/AGRENER2004/Fscommand/PDF/Agrener/Trabalho 59.pdf>

SILVESTRE, W. V. D. et al. Morphological and physiological responses of açaí seedlings subjected to different watering regimes. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 20, n. 4, p. 364–371, 2016.

ABNT. **NBR 14810-1 Painéis de partículas de média densidade. Parte 1: Terminologia.** Rio de Janeiro: Associação Brasileira de Normas Técnicas, 2013.

XAVIER, D. J. C. et al. **O beneficiamento do açaí no projeto modelo de negócio de energia elétrica em comunidades isoladas na Amazônia - NERAM.** Campinas: ENCONTRO DE ENERGIA NO MEIO RURAL, 6, 2006. Disponível em: <http://www.proceedings.scielo.br/scielo.php?script=sci_arttext&pid=MSC0000000022006000200014&lng=pt&nrm=abn>

AUTORES

ORCID: https://orcid.org/0000-0002-6471-8949
BRENNA PAULA BOAVENTURA CORRÊA CAVALCANTI, M.Sc. | Universidade Federal do Amazonas – UFAM - Mestrado Profissional em Design, Manaus, AM, Brasil | Endereço para correspondência: Rua Professor Samuel Benchimol, nº 543, Condomínio Condomínio Mais Passeio do Mindu, Torre 2, Apartamento 602 – Parque 10, Manaus-Am – CEP 69055-705. | e-mail: brennacavalcanti@gmail.com

ORCID: https://orcid.org/0000-0001-7811-3564
GERALDO LIRA DE SOUZA, M.Sc. | Universidade Federal do Amazonas – UFAM - Mestrado Profissional em Design, Manaus – AM,Brasil | Endereço para correspondência: Rua Júlio Verne, 121 Condomínio Sol Nascente 2 Bl H Ap 102 – Aleixo, Manaus-Am – CEP 69060-770. | e-mail: geraldolira05@gmail.com

ORCID: https://orcid.org/0000-0002-2769-2663
ACURSIO YPIRANGA BENEVIDES JÚNIOR, M.Sc. | Universidade Federal do Amazonas – UFAM | Design, Manaus, AM. Correspondência para: Rua Brigadeiro João Camarão, n. 305, Condomínio Pq dos Franceses, Bloco 7ª, apartamento 403, Manaus – AM, CEP: 69040080 | email: acursiobenevides@gmail.com

ORCID: https://orcid.org/0000-0001-5686-3209
CLAUDETE BARBOSA RUSCHIVAL, Dra. | Universidade Federal do Amazonas – UFAM, Design – Manaus, AM, Brasil | Endereço para correspondência: Av. Senador Raimundo Parente, 70 - bloco 16C, apto 205. Manaus – AM, CEP 69048-662. | e-mail: b_claudete@hotmail.com

ORCID: https://orcid.org/0000-00001-58745492
MAGNÓLIA GRANGEIRO QUIRINO, Dra. | Universidade Federal do Amazonas – UFAM | Design, Manaus, AM. | Endereço para correspondência: Avenida do Turismo, 295. Bairro: Tarumã. CEP: 69041-010. Manaus - AM. | e-mail: mquirino@ufam.edu.br

ORCID: https://orcid.org/0000-0002-7283-1458
DANIEL FERREIRA DE CASTRO, Dr. | Universidade Federal do Amazonas – UFAM - Mestrado Profissional em Design, Manaus – AM,Brasil | Endereço para correspondência: Rua Júlio Verne, 121 Condomínio Sol Nascente 2 Bl H Ap 102 – Aleixo, Manaus-Am – CEP 69060-770. | e-mail: danmao@ufam.edu.br

COMO CITAR ESTE ARTIGO

CAVALCANTI, Brenna Paula Boaventura Corrêa; SOUZA, Geraldo Lira de; BENEVIDES Jr., Acursio Ypiranga; RUSCHIVAL, Claudete Barbosa; QUIRINO, Magnólia Grangeiro; CASTRO, Daniel Ferreira de. Feasibility Study For The Usage Of The Acai Stone As Reinforcement For The Modeling Of Plant Polyurethane Matrix Composite Material. **MIX Sustentável, [S.l.], v. 7, n. 3, p. 19-28, ago. 2021**. ISSN 24473073. Disponível em:<http://www.nexos.ufsc.br/index.php/mixsustentavel>. Acesso em: dia mês. ano. doi:https://doi.org/10.29183/2447-3073.MIX2021.v7.n3.19-28.

DATA DE ENVIO: 04/02/2020
DATA DE ACEITE: 18/03/2021