REINVENT: A PROJECT COMPOSITE SUSTAINABLE

REINVENTE: COMPÓSITO SUSTENTÁVEL PARA EMBALAGEM

REINVENT: COMPOSITE SOSTENIBLE PARA EMBALAJE

ISABELLA CHRISTINA DE LIMA E SANTOS | UTFPR – Universidade Tecnológica Federal do Paraná, Brasil
UGO LEANDRO BELINI | UTFPR – Universidade Tecnológica Federal do Paraná, Brasil
ANDRÉ CHRISTIAN KEINERT | UTFPR – Universidade Tecnológica Federal do Paraná, Brasil

ABSTRACT
The consumption habits of people over the years have led to a significant environmental impact. In the pursuit of development that is less harmful to the environment, one possible alternative is the development of composites that include plant-based products in their composition. Thus, this project discusses the use of sugarcane bagasse with lignin-based resin in a composite, applied to a new packaging design solution. The obtained composites used a medium granulometric fraction of sugarcane bagasse, bound with 30% lignin-based resin/particles, and manufactured in a pressing cycle of: 3 t, 100ºC, 10 min, achieved with an average density of 750 kg/m^3. Workability tests were conducted in laboratories, such as processing, drilling, and sanding, which presented satisfactory results that allow the applicability of the composite. The material obtained proved to be light, resistant, with satisfactory texture and appearance. A brainstorming session was conducted on the application of the composite, and it was decided to apply it in packaging for higher value-added products .The prototype, called Reinvente, has a rustic look, practicality, versatility, and easy handling. A survey was conducted with a group of people to validate the prototype. Therefore, it was observed that the composite is an excellent alternative material to be used in the creation of bioengineering projects and interior design, combining aspects of innovation and the environment.

KEYWORDS
Sustainability; Sugar cane bagasse; Lignin Resin; New Products.

RESUMO
Os hábitos de consumo das pessoas ao longo dos anos levaram a um impacto ambiental significativo. Na busca por um desenvolvimento menos nocivo ao meio ambiente, uma possível alternativa é o desenvolvimento de compósitos que incluam produtos de base vegetal em sua composição. Assim, este projeto discute o uso de bagaço de cana-de-açúcar com resina à base de lignina em um compósito, aplicado a uma nova solução de design de embalagens. Os compósitos obtidos utilizaram uma fração granulométrica média do bagaço de cana-de-açúcar, vinculada com 30% de resina/partículas à base de lignina, e fabricados em um ciclo de prensagem de: 3 t, 100ºC, 10 min, alcançando uma densidade média de 750 kg/m^3*. Foram realizados testes de trabalhabilidade em laboratórios, como processamento, perfuração e lixamento, que apresentaram resultados satisfatórios, permitindo a aplicabilidade do compósito. O material obtido mostrou-se leve, resistente, com textura e aparência satisfatórias. Uma sessão de brainstorming foi realizada sobre a aplicação do compósito, e decidiu-se aplicá-lo em embalagens para produtos de maior valor agregado. O protótipo, chamado Reinvente, possui um aspecto rústico, praticidade, versatilidade e fácil manuseio. Foi realizada uma pesquisa com um grupo de pessoas para validar o protótipo. Portanto, observou-se que o compósito é um excelente material alternativo a ser utilizado na criação de projetos de bioengenharia e design de interiores, combinando aspectos de inovação e meio ambiente.*

http://dx.doi.org/10.29183/2447-3073.MIX2024.v10.n3.231-242
ISSN: 2447-0899 (IMPRESSA) | 2447-3073 (ONLINE)
Mix Sustentável | Florianópolis | v.10 | n.3 | p.231-242 | AGO. | 2024

PALAVRAS-CHAVE
Sustentabilidade; Bagaço de Cana-de-Açúcar; Resina de Lignina; Novos Produtos.

RESUMEN
La forma de consumo de las personas a lo largo de los años ha tenido un gran impacto ambiental. En la búsqueda de un desarrollo que dañe menos el medio ambiente, una posible alternativa es el desarrollo de composites que contengan productos de origen vegetal. Así, este proyecto analiza el uso de bagazo de caña de azúcar con resina a base de lignina en un composite, aplicado en una nueva solución al diseño de envases. Los composites obtenidos utilizaron una fracción granulométrica promedio de bagazo de caña de azúcar, ligada con un 30% de resina/partículas a base de lignina y fabricados en un ciclo de prensado de: 3 t, 100ºC, 10 min, obtenidos con una densidad promedio de 750 kg/m³. Se realizaron pruebas de trabajabilidad en laboratorios, como procesamiento, taladrado y lijado, las cuales presentaron resultados satisfactorios que permiten la aplicabilidad del composite. El material obtenido resultó ser ligero, resistente, de textura y apariencia satisfactoria. Se realizó una lluvia de ideas sobre la aplicación del composite y se decidió aplicarlo en envases para productos de mayor valor agregado (PMVA). El prototipo, denominado Reinvente, tiene aspecto rústico, practicidad, versatilidad y fácil manejo. Se realizó una encuesta a un grupo de personas para validar el prototipo. Por lo tanto, se observó que el composite es un gran material alternativo para ser utilizado en la producción de proyectos de bioingeniería y diseño de interiores, combinando aspectos de innovación y medio ambiente.

PALABRAS CLAVE
Sostenibilidad; Bagazo de caña de azúcar; Resina a base de lignina; Nuevos productos.

1. INTRODUCTION

The significant industrial growth observed over the years has changed people's consumption patterns and has led to a considerable environmental impact. Thus, sustainable innovation becomes unavoidable and should not be dismissed. It is necessary to adopt sustainable development alternatives in which the production of goods and services preserves diversity and respects the integrity of ecosystems (DIAS, 2015).

Therefore, a reorientation of social behaviors is necessary, encouraging the search for products and services that adopt and promote sustainable alternatives. The transition from this form of material consumption should be driven by choice, that is, by recognizing each as an opportunity to improve well-being (MANZINI; VEZZOLI, 2002). In this process, an evident alternative is the development of composites that include products of vegetable origin in their composition. A composite can be considered as the combination of properties of two or more distinct materials, resulting in a new material (CALLISTER; RETHWISCH, 2018).

One of the possibilities for developing composites, as a solution to Design, is the use of sugarcane bagasse with lignin-based resin, which was the focus of the project study. The research brought innovation based on the reuse of by-products that would otherwise be discarded. Thus, the focus was on studying a potential application for the developed composite, considering its utility and the optimization of its life cycle.

1.1 OBJECTIVES

The objective of this work was to develop a composite made from sugarcane bagasse combined with lignin-based resin and apply it to a sustainable packaging that could be reused for other purposes. To achieve this objective, the aim was to understand Design, Sustainability, and their relationship, as well as to define what composites are. This understanding enabled the progression to the production stages and the application in a prototype.

2. DESIGN FOR SUSTAINABILITY

In 1750, the Industrial Revolution began in England, introducing a new production model, changing traditional artisanal products, and establishing various aesthetic movements. This gave rise to Design, which, according to Manzini and Vezzoli (2002), encompasses all territorial project activities, as well as graphic design, architecture, and consumer goods. These activities involve a creative process focused on the needs of the population, aiming to enhance their well-being (HSUAN-AN, 2018).

Thus, the designer has the role of creating effective solutions to societal demands, transforming them into concrete results (HSUAN-AN, 2017). Among these challenges, the professional can also contribute to sustainability by choosing materials that favor environmental preservation, linking the technically possible with the ecologically necessary, and creating proposals that are socially and culturally meaningful (MANZINI; VEZZOLI, 2002).

The significant industrial growth observed over the years has changed people's consumption patterns and led to a considerable environmental impact (DIAS, 2015). As a result, sustainable innovation becomes unavoidable and should not be dismissed. Therefore, a reorientation of social behaviors is necessary, encouraging the search for products and services that adopt and promote sustainable alternatives (MANZINI; VEZZOLI, 2002).

In this context, aesthetics play a fundamental role in the design of these new products because sustainable innovation, if not perceived as an improvement, is insufficient. The entire set of characteristics that make the product attractive must be considered (VEZZOLI, 2010). Thus, it is the designer's task to create projects that provide innovation, ideas, and new concepts, understanding how to make them aesthetically captivating, and designing with all stages in mind to convey to consumers the conscious vision necessary to achieve sustainability (MANZINI, 2008).

One way to offer sustainable alternatives to consumers is through what the term upcycling proposes. Coined by Reine Pilz in 1994 and popularized by William McDonough and Michael Braungart, this process involves the reuse or repurposing of materials that would otherwise be discarded, maintaining the essence of the original product, even if the initial function is altered (SILVA et al., 2012). In this process, an evident alternative is the development of composites that include natural-origin products in their composition.

3. COMPOSITE MATERIALS

The emergence of composites as materials occurred in the mid-20th century with the production of multiphase composites. The recognition of this new way of combining materials led to the identification of composites as a distinct new class separate from traditional metals, ceramics, and polymers (CALLISTER, RETHWISCH, 2018).

From this, we can understand that composites are the union of two or more materials used together to result in a new combination of properties. They can be selected to achieve combinations of stiffness, mechanical strength, density, performance at high temperatures, corrosion resistance, hardness, and conductivity (ASKELAND, WRIGHT, 2014).

Considering these different characteristics, these materials can have various applications depending on factors such as structural performance, cost, availability of raw materials, and the progress of their manufacturing process, among other parameters (NETO, PARDINI, 2018).

3.1 Fiber-Reinforced Composites

There are various methods for producing composites, depending on the application and materials. Short fiber--reinforced composites are formed by mixing fibers with a liquid or plastic matrix and then using relatively conventional techniques, such as injection molding for polymer--based composites or casting for metal matrix composites (ASKELAND; WRIGHT, 2014).

To produce composites with plant-based materials, it is necessary to achieve the proper mixing of fibers, select the appropriate matrix, apply suitable surface treatments, and, if necessary, use low-cost manufacturing techniques. This ensures greater adhesion, reduced moisture, and lower sensitivity in the composites (SATYANARAYANA, 2010).

The use of plant-based fibers in a composite primarily aims to create a sustainable and cost-effective material. One possibility for developing a plant-based composite is the use of sugarcane bagasse with resin, which is the focus of this project.

3.2 Sugarcane bagasse

Introduced by the Portuguese in the 1530s, sugarcane cultivation is one of the oldest forms of agriculture and a symbol of the Brazilian territory. According to data from the Food and Agriculture Organization of the United Nations (FAO), since 1980, Brazil has become the world's largest producer of sugarcane (IBGE, 2017).

Almost all by-products of sugarcane can be utilized. Among them, sugarcane bagasse stands out. It is a fibrous residue from the extraction of juice through the mills. The amount produced depends on the fiber content of the processed cane, with an average of 46% fiber and 50% moisture, resulting in approximately 280 kilograms of bagasse per ton of processed cane (ALCARDE, 2009).

3.3 Lignin-based resin

Lignin is a biopolymer derived from plants that provides structure and rigidity to wood and plants, acts as an internal transport system for nutrients and water, and protects against microbial attacks. However, lignin can also be found as a by-product in the paper industry, during the process of extracting cellulose from wood, known as pulping, which reduces wood to cellulose pulp (CALVO-FLORES et al., 2015).

4. METHODOLOGY

To ensure the project's success in its technical development aspects, the composite was produced following the methodology outlined by Mike Baxter (2011) in 'Product Design: Practical Guide for Designing New Products.' To create an effective market solution in design, it was necessary to gather information and opinions from potential consumers. For this purpose, part of the methodology from Gavin Ambrose (2011) in 'Design Thinking' was used, considering that the project's development timeline did not allow for the full implementation of the proposed methodology.

For better understanding, the process adopted in the work was divided into the following stages: (a) Definition; (b) Analysis; (c) Material Analysis; (d) Idea Generation; (e) Production; (f) Feedback and Communication.

4.1 Equipment

The equipment used in the production of the composite included: a Lucadema drying and sterilization oven at 70°C (Figure 01), a Marconi hydraulic press for crushing with heating (Figure 02), waterproof Teflon sheet for the

https://doi.org/10.29183/2447-3073.MIX2024.v10.n3.231-242

thermal press, wooden board for mold support, MDF mold for depositing the mixture, plastic containers for holding the resin and fiber, rubber gloves, a 10kg digital scale Original Line model SL0363, and a plastic tray for mixing (Figure 03).

Figure 01: Drying and Sterilization Oven.
Source: Authors.

Figure 02: Hydraulic Press for Crushing with Heating.
Source: Authors.

Figure 03: Other materials used.
Source: Authors.

To divide the sugarcane bagasse, granulometric sieves with mesh openings of 2 and 7 millimeters were used (Figure 04), making it possible to separate the fibers into 3 different sizes.

Figure 04: Granulometric Sieves.
Source: Authors.

4.2 Materials

The phenol-lignin-formaldehyde resin used in this work was Eco Residur, supplied by GPC Química. It is a dark red liquid resin (Figure 05). According to the analysis report provided by the company, it is suitable for bonding wood products and porous materials in general, such as water-resistant plywood, cement fiber, and others.

Figure 05: Lignin-Based Resin.
Source: Authors.

It has a shelf life of 60 days when stored at an average temperature of 25°C. At low temperatures (below 10°C), it is stable, but its viscosity increases, while at high temperatures, its shelf life is reduced. It is advisable to use gloves, safety goggles, and an apron when handling it. Curing occurs with heat, starting from 6 minutes at 100°C.

https://doi.org/10.29183/2447-3073.MIX2024.v10.n3.231-242

The sugarcane bagasse used was donated by a sugar and alcohol plant in the interior of São Paulo. The material underwent drying and granulometric separation. The separation was done to divide the fibers into 3 sizes: fine, medium, and coarse (Figure 06).

First, the fine fibers were separated using a 2-millimeter mesh sieve. Subsequently, the division between medium and coarse fibers was done using a 7-millimeter mesh sieve.

Figure 06: Sugarcane Bagasse Fibers Separated into Fine, Medium, and Coarse.
Source: Authors.

4.3 Composite Production

Initially, to determine the amount of material to be used in the manufacturing process, a volume calculation was performed based on the dimensions of the available mold and the desired thickness of the plate. Next, the density of the desired plate was calculated, using the density of MDF as a reference, which corresponds to $1m^3 = 700$ kg. This allowed for the determination of the amount of fibers needed.

Thus, the amount of sugarcane bagasse used was approximately 90 grams. To determine the resin dosage, the non-volatile content of the resin was considered, which is 51% of the total. The values used in production were varied to understand how the material would behave, and were adjusted based on the results obtained.

With this, it was possible to proceed with the composite production. First, the fibers were separated according to the desired size into a container and weighed on a scale. Then, the resin was poured into another container and weighed. Next, the fibers were placed in a tray, and the resin was gradually poured over them, mixing the two materials (Figure 07).

Figure 07: Preparation of the Fibers.
Source: Authors.

Next, the mixture was placed into the MDF mold to accommodate the material. The mold was supported on a wooden board with the Teflon sheet underneath to prevent the material from sticking to the heated plate. Then, another Teflon sheet was placed on top, and the setup was placed into the hydraulic press (Figure 08).

Figure 08: Shaped Fibers Ready for the Press.
Source: Authors.

5. EXPERIMENTATION

To better understand the behavior of the materials, several samples were made, varying the amount of resin and fiber granulometry. All variations yielded different results, demonstrating the vast potential of composite materials.

The following samples were subjected to 100°C with a pressure of 3 tons and a total time of 10 minutes: (a) 90g of medium fiber and 18g of resin; (b) 90g of fine fiber and 38g of resin; (c) 90g of coarse fiber and 38g of resin; (d) 90g of coarse fiber and 18g of resin; (e) 90g of medium fiber and 27g of resin; (f) 90g of fine fiber, 27g of resin, and a piece of jute; (g) 90g of medium fiber and 38g of resin (Figure 09).

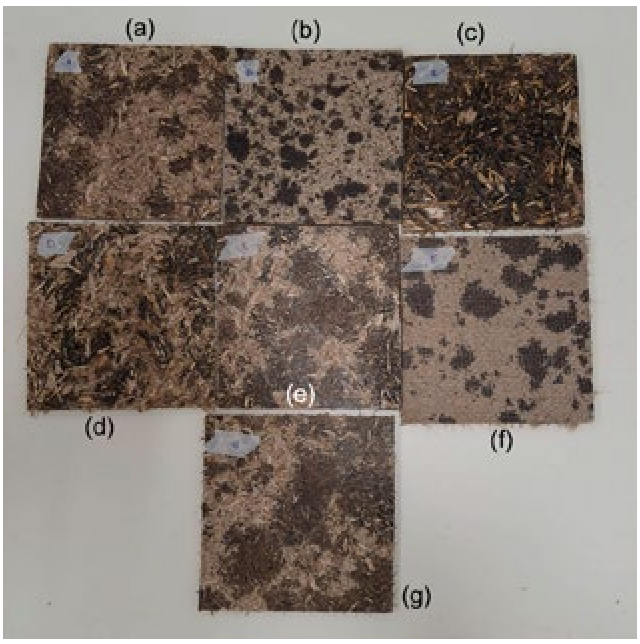

Figure 09: First Batch of Samples.
Source: Authors.

The following samples were subjected to 180°C, with a pressure of 2 tons and a time of 5 minutes: (a) 90g of coarse fiber and 18g of resin; (b) 90g of medium fiber and 27g of resin (Figure 10).

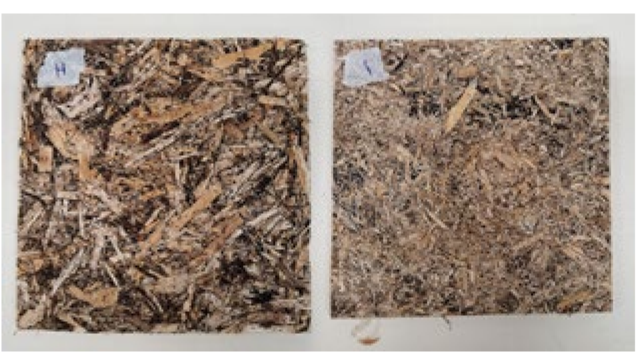

Figure 10: Second Batch of Samples.
Source: Authors.

The following samples were subjected to 120°C, with a pressure of 2 tons and a time of 8 minutes: (a) 90g of medium fiber and 27g of resin; (b) 90g of coarse fiber and 18g of resin (Figure 11).

Figure 11: Third Batch of Samples.
Source: Authors.

The samples that were exposed to higher temperatures and/or pressures and times exhibited a drier appearance, making the fibers more brittle. To understand the material's behavior during machining, the samples were subjected to a band saw (Figure 12), a drill with different sizes of bits (Figure 13), and also a cut with Computer Numerical Control (CNC) (Figure 14). It was also displayed in possible

Figure 12: Machining with Band Saw.
Source: Authors.

Figure 13: Machining with Drill.
Source: Authors.

Figure 13: Machining with CNC.
Source: Authors.

This allowed us to define some requirements for proceeding to the next stages. It was observed that the sample with fine fibers, despite having higher resin absorption and thus greater difficulty in distribution, exhibited greater resistance to machining. In contrast, the medium and coarse fiber samples, particularly those with lower amounts of resin, tended to come apart more easily, forming more burrs and resulting in a more fragile piece.

The sample chosen for the next phase was the one with medium fibers, as it allowed for better resin distribution and less material loss during machining compared to the coarse fibers. The amount of resin was increased to 50%, or 45 grams, to provide greater resistance.

6. CONCEPT

According to Baxter (2011), the conceptual design aims to produce principles for a new product, meeting consumer demands and differentiating it from existing products on the market. This allows for the development of basic lines of the desired form and function. By incorporating the concept of sustainability into the project, the goal was to apply the requirement of eco-efficiency to the system, known as system life optimization. This requirement aims to extend the product's life and enhance its use. Thus, a product with a longer life than another with the same function generally implies a lower environmental impact (VEZZOLI, 2010). Consequently, the product has a primary function, but once in the possession of the end user, it may serve additional functions.

Considering that the material studied did not achieve satisfactory results in organic forms, the product needed to have flat shapes, i.e., be geometric. Therefore, the specified concepts were: (a) Functionality; (b) Life optimization; (c) Practicality.

To ensure that the prototype could be easily identified and remembered, a name was created for the project. Taking into account the reuse of materials, a suggestion for a product different from the conventional, and the optimization of the product's lifespan, the project was named "Reinvente" (Reinvent). Thus, it encompasses its already defined concepts: Reinvent the way you consume, Reinvent the way you produce, and Reinvent new ways to use.

7. PROTOTYPE

Upon determining the product configuration, with the 3D model and technical drawings defined, and preparing the specifications for manufacturing, the cutting of the pieces was carried out using the CNC machining method (Figure 15).

Figure 15: Machining of the parts for the prototype.
Source: Authors.

A varnish was applied to the parts to provide greater resistance and durability to the product, as well as to give a more aesthetically pleasing finish. Glue was used to reinforce the joints, providing increased durability. For this work, Marine Varnish Poliulack from Sayerlack and White Glue Polyvinyl Acetate - PVA Extra from Mundial Prime were used, both of which are water-based materials.

7.1 Finalization

To better visualize the prototype, studio photos were taken with detailed framing (Figures 16 and 17).

Figure 16: Detailed photos of the prototype.
Source: Authors.

Figure 17: Detailed photos of the prototype.
Source: Authors.

It was also displayed in possible everyday scenarios. The first demonstrated its primary use as a perfume packaging (Figure 18). The second shows its use as a jewelry holder (Figure 19), and the third shows the separated packaging, with one part used as a key holder and the other part for storing received letters (Figure 20).

Figure 18: First use scenario: perfume packaging.
Source: Authors.

Figure 19: Second use scenario: jewelry holder.
Source: Authors.

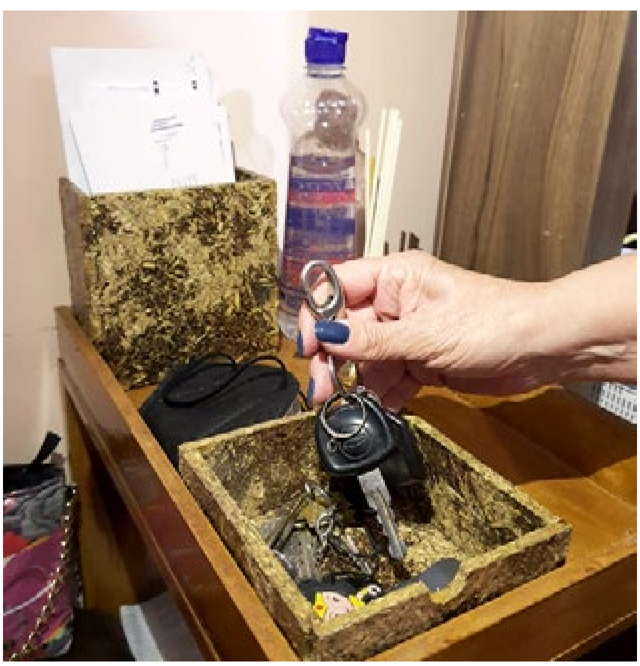

Figure 20: Third use scenario: cachepot.
Source: Authors.

8. FEEDBACK

To gather validation information on the usability of the developed prototype, analyzing possible changes and future improvements, a form was created on the Google platform to obtain feedback. The survey was divided into three parts: knowledge of the study area, product analysis, and finally, functionality, including photos and relevant information, and did not include the identification of the respondents.

Most respondents considered it important to have products in this production line and would purchase them if they were less expensive than conventional ones, as most could not determine if they would buy them if the cost were higher. They also found both designated functionalities for the packaging to be valid.

They liked the idea and concept of the project, considering the importance of sustainability as hope for a better future and the relevance of material reuse. Aesthetically, it was considered rustic, which pleased most people.

Due to the project's tight deadline, it was not possible to implement the subsequent stages of research and product improvement. However, the importance of obtaining more feedback for the continuous refinement of the product is recognized.

9. FINAL CONSIDERATIONS

The proposal to obtain a composite from sugarcane bagasse, bound with lignin-based resin, was feasible. This research successfully combined aspects of sustainability and innovation in the environment by utilizing residual biomass bound with a 30% dosage of resin particles that contain, in their composition, residual black liquor from the cellulose extraction process.

The effectiveness of the pressing cycle used (3 t, 100ºC, 10 min) was demonstrated, and the obtained composites had an average density of 750 kg/m^3, allowing for excellent performance in workability and surface aspects. Combined with CNC machining for glue-free joints, this enabled the creation of a prototype packaging designed for high-value products, such as perfumes and jewelry.

According to the feedback received from the evaluation group, the prototype exhibited a rustic appearance and excellent functionalities for packaging, and the importance of projects with sustainability and material reuse aspects was emphasized.

Thus, the prototype, named "Reinvente," features a rustic look, practicality, versatility, and ease of handling. It is noted that the composite is a great alternative material for use in bioengineering projects and interior design, merging aspects of sustainability, innovation, and the environment.

This was an exploratory project, utilizing plant-based residues to propose a new type of composite, aiming to provide relevant information and encourage the study of new materials. For future work, considering the potential already demonstrated, it is recommended to observe the resin's lifespan according to the project, use higher capacity equipment to evaluate new uses and applications in larger composites, base research on applying the resin to other types of fibers, its extraction and pressing cycle, deepen its mechanical and technical characterizations, and disseminate the obtained knowledge so that other researchers can conduct new studies.

REFERENCES

ALCARDE, Ricardo André. **Outros produtos: Cana-de-Açúcar**. Agência Embrapa de Informação Tecnológica – Ageitec. Brasília, 2009, Disponível em: <www.agencia.cnptia.embrapa.br/gestor/cana-de-acucar/arvore/CONTAG01_108_22122006154841.html>

AMBROSE, Gavin; HARRIS, Paul. **Design thinking** (livro eletrônico).Tradução Mariana Belloli. 3. ed. Porto Alegre: Bookman, 2011. Tradução de: Basics Design 08: Design Thinking.

ASKELAND, Donald R.; WRIGHT, Wendelin J.. **Ciência e engenharia dos materiais**. Tradução Solange Aparecida Visconti. 3. ed. São Paulo: Cengage Learning, 2014. Tradução de: Essentials of materials science and engineering.

BAXTER, Mike. **Projeto de produto**: guia prático para o design de novos produtos. Tradução Itiro Iida. 3. ed. São Paulo: Blucher, 2011. Tradução de: Product design: a practical guide to systematic methods of new product development.

BRUMATTI, Gabriela. **Entrando no vermelho**: planeta está prestes a esgotar os recursos naturais que tinha para 2021. G1. Campinas e Região, 2021. Disponível em: https://g1.globo.com/sp/campinas-regiao/terra-da-gente/noticia/2021/07/28/entrando-no-vermelho-planeta-esta-prestes-a-esgotar-os-recursos-naturais-que-tinha-para-2021.ghtml. Acesso em: 31 jul. 2021.

CALLISTER, William D.; RETHWISCH, David D. . **Ciência e Engenharia de Materiais**: Uma introdução (livro eletrônico). Tradução Sergio Murilo Stamile Soares. 9. ed. Rio de Janeiro: Livros Técnicos e Científicos Editora Ltda, f. 362, 2018. 724 p. Tradução de: Materials science and engineering: an introduction.

CALVO-FLORES, Francisco G. et al. **Lignin and Lignans as Renewable Raw Materials**: Chemistry, Technology and Applications. Reino Unido: Wiley, f. 256, 2015. 512 p.

DIAS, Reinaldo. **Sustentabilidade**: origem e fundamentos; educação e governança global; modelo de desenvolvimento (livro eletrônico). São Paulo: Atlas, 2015.

HSUAN-AN, Tai. **Design**: conceitos e métodos (livro eletrônico). 1. ed. São Paulo: Blucher, 2018. 320 p.

IBGE. **A Geografia da Cana-de-Açúcar**. Rio de Janeiro, IBGE, 2017, Disponível em: < https://biblioteca.ibge.gov.br/>. Acesso em: 10 jul 2021.

MANZINI, Ezio; VEZZOLI, Carlo. **O Desenvolvimento de produtos sustentáveis**: os requisitos ambientais dos produtos industriais. Tradução Astrid de Carvalho. São Paulo: Edusp, 2002. Tradução de: Lo sviluppo di prodotti sostenibili: I requisiti ambientali dei prodotti industriali.

MANZINI, Ezio. **Design para inovação social e sustentabilidade**: comunidades criativas, organizações colaborativas e novas redes projetuais. Rio de Janeiro: E-papers, 2008.

NETO, Flamínio Levy; PARDINI, Luiz Claudio. **Compósitos estruturais**: ciência e tecnologia (livro eletrônico). 2. ed. São Paulo: Blucher, f. 157, 2018. 313 p.

ROMERO, Luiz Lauro et al. **Fibras artificiais e sintéticas**. BNDES Setorial, Rio de Janeiro, n. 1 , p. [54]-66, jul. 1995

SATYANARAYANA, K. G. **Biodegradable polymer composites based on brazilian lignocellulosic**. Revista Matéria, v. 15, n. 2, p. 088-095, 2010.

SILVA, Christian Luiz da; JUNIOR, Eloy Fassi Casagrande; LIMA, Isaura Alberton de; SILVA, Maclovia Corrêa da; AGUDELO, Libia Patricia Peralta; PIMENTA, Rosângela Borges. **Inovação e Sustentabilidade**. Curitiba: Aymará Educação, 2012.

VEZZOLI, Carlo. **Design de Sistemas para a Sustentabilidade**: teoria, métodos e ferramentas para o design sustentável de "sistemas de satisfação". Salvador: EDUFBA, 2010. 342 p.

AUTHORS

ISABELLA CHRISTINA DE LIMA E SANTOS. Designer. DADIN/ Universidade Tecnológica Federal do PR. Av. Sete de Setembro, 3165 Rebouças, Curitiba-PR, 80230-901. E-mail: isachris111@gmail.com

UGO LEANDRO BELINI. Eng. Florestal. DADIN/PPGSAU/ Universidade Tecnológica Federal do PR. Av. Sete de Setembro, 3165 Rebouças, Curitiba-PR, 80230-901. E-mail: ubelini@utfpr.edu.br

ANDRÉ CHRISTIAN KEINERT. Eng. Ind. Madeireiro. Doutorando PPGSAU/Universidade Tecnológica Federal do PR. Av. Sete de Setembro, 3165 Rebouças, Curitiba-PR, 80230-901. E-mail: andrechristiankeinert@gmail.com

HOW TO CITE THIS ARTICLE:

SANTOS, Isabella Christina de Lima e; BELINI, Ugo Leando; KEINERT, André Christian. Reinvent: A project composite sustainable. **MIX Sustentável**, v. 10, n. 3, p. 231-242, 2024. ISSN 2447-3073. Disponível em: <http://www.nexos.ufsc.br/index.php/mixsustentavel>. Acesso em: _/_/_.doi: <https://doi.org/10.29183/2447-3073.MIX2024.v10.n3.231-242>.

SUBMETIDO EM: 18/06/2023
ACEITO EM: 13/08/2024
PUBLICADO EM: 15/08/2024
EDITORES RESPONSÁVEIS: Lisiane Ilha Librelotto e Paulo Cesar Machado Ferroli

Record of authorship contribution:
CRediT Taxonomy (http://credit.niso.org/)

ICLS: conceptualization, data curation, research and writing - review and editing.

ULB: conceptualization, methodology, research and writing - review and editing.

ACK: formal analysis, methodology and writing - original draft.

Conflict declaration: nothing has been declared.