Sugarcane bagasse reinforced composite material in the creation of eco-friendly jewellery

Material compósito reforçado com bagaço da cana-de-açúcar na criação de ecojoias

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ABSTRACT

There is currently a lot of discussion about the environmental impacts of the fashion industry. The designer, as a transformative agent in this process, has the responsibility to incorporate sustainable production methods and products to minimise such impacts. It is in the context of sustainability that has emerged MDF (*Medium Density Fiberboard*), low-cost ecological panels with different applications, including usage in fashion accessories. However, MDF is responsible for releasing formaldehyde into the atmosphere, causing risks to life on the planet. Therefore, this research aims at the development of composite material to replace it, so we used sugarcane bagasse in the fabrication of eco-friendly jewellery. Methodologically, bibliographical research was conducted, followed by hypothetical-deductive experimental research. Furthermore, laboratory tests were carried out, such as absorption tests by immersion of liquids, swelling in thickness and impact. Finally, the results were analysed, proving sugarcane bagasse's viability in producing eco-friendly jewellery.

Keywords: Sustainability. Sugar cane. MDF. Composite. Eco jewellery.

RESUMO

Atualmente muito se discute sobre os impactos ambientais da indústria da moda. O designer, como agente transformador nesse processo, tem a responsabilidade de incorporar a sustentabilidade aos seus métodos de produção e produtos de forma a minimizar tais impactos. É no contexto da sustentabilidade que surge o MDF (Medium Density Fiberboard), painéis ecológicos de baixo custo e com diferentes aplicações, inclusive para a aplicação em acessórios de moda. O MDF, porém, é responsável por *liberações de formol na atmosfera, causando riscos à vida no planeta. Dessa forma, esta pesquisa tem por objetivo desenvolver um compósito para substituir o MDF e, com esse intuito, fez-se uso do bagaço da cana-de-açúcar para aplicação no desenvolvimento de ecojoias. Metodologicamente desenvolveu-se uma pesquisa bibliográfica seguida de uma pesquisa experimental com abordagem hipotético-dedutiva. Ademais, foram realizados ensaios laboratoriais, como testes de absorção por imersão de líquidos, de inchamento em espessura e de impacto. Por fim, os resultados foram analisados, o que comprovou a viabilidade desse material na produção de ecojoias.*

Palavras-chave: *Sustentabilidade. Cana-de-açúcar. MDF. Compósito. Ecojoias.*

1 INTRODUCTION

Sustainability in the Fashion Industry is one of the focuses of contemporary discussions as it is one of the most economically relevant industries and which, however, is full of problems involving environment. Even with these issues, capitalist thinking still prevails. Therefore, it is necessary to work on Sustainable Consumption in the current economic model. Therefore, designers and entrepreneurs must develop products that can have a longer useful life (Goworek *et al*., 2018) and, in addition, there must be stimulation of sustainable consumption patterns, which can occur through the awareness of a population driven by consumption and easy disposal (Tunn *et al*., 2019) and the recovery and reuse of materials and components at the end of their life (Islan; Bhat, 2019).

Medium Density Fiberboard (MDF) has become a widely used material in the furniture industry, but it has different indications, including the production of fashion accessories, considering it is a versatile, low-cost, and environmentally friendly material produced with reforested wood. However, Misucochi *et al*. (2022) report that its disposal is such a big problem, as it either does not have a correct destination or it is used as an input for burning, potentially releasing harmful gases such as formaldehyde, a gas present in its composition, which poses risks to life when in large concentrations.

In view of the above, this work aims to develop a sustainable composite material made from sugarcane bagasse, which is used as raw material and applied in the development of eco-friendly jewellery, replacing MDF. It must be more sustainable than MDF and reinforced in terms of its chemical and physical characteristics.

Pointing out the objectives of this work, a hypothetical-deductive experimental research methodology was used, which has been divided into three phases. The work ends with final considerations based on the research process, testing and development of the eco-friendly jewellery collection.

2 ECO-FRIENDLY JEWELLERIES

The environmental crisis scenario of the 21st century has led to the emergence of several events for discussion and since 1987, when the Brundtland Commission of the United Nations defined the concept of sustainable development, sustainability has been disseminated by calling for market, government and society to respect the environment and the lives of future generations by reducing the impact on the natural environment and/or increasing the beneficial impact on local communities and society in general (Kemper; Ballantine, 2019).

Within this current environmental framework, emphasis must be given to the Fashion Industry, as it is considered one of the most polluting industries in the world due to the production model adopted, a rapid and voluminous production that turns obsolete in a short period of time, going against sustainable development and becoming even worse because today consumption is directed not only to material goods but also, and mainly, to immaterial goods, in the form of experiences (Albuquerque, 2022).

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This is an industry that needs to keep growing as it is one of the best sources of economic growth, promoting jobs and income. It is not about reducing production or consumption, it's about responsible production with a careful study of processes and the reuse of waste produced. There is, therefore, an urgent need for a model that is opposite to the current one based on fast fashion and *slow fashion*, which operates on smaller scales, developing a relationship between designer and consumer, product, and environment.

The slow concept, according to Macena, Marques and Broega (2018), is associated with timeless and durable pieces whose quality and exclusivity are achieved using raw materials and differentiated finishes. In addition, slow fashion features local production with a focus on environmental and socio-cultural benefits that provide new business models and new opportunities.

The designer, in this context, must direct his creation to products that, in addition to being aesthetic and functional, incorporate sustainable principles from renewable materials, recyclable and reuse processes or even that are the result of social work. In this way, he manages to transmit the mentality of change to consumers, transforming the fashion cycle into a sustainable cycle. Then, this is the main current question: how to combine sustainable development with industrial economic growth to create a better quality of life for current and future generations?

Fashion professionals are expected to think cyclically and creatively and adapt to the needs of the postmodern world. This is a professional with sociocultural responsibility (Saltoratto *et al*., 2019) who is capable of working with raw materials from renewable sources; with materials that require reduced levels of inputs (water, energy and chemical substances), as well as those that generate less waste, such as recyclable and biodegradable fibres; and, finally, they must promote fair working conditions.

Questions about sustainability and the choice of environmentally friendly products determine the market and the form of production. Furthermore, their post-purchase life cycle is also a much-discussed topic, which makes it necessary to discuss the excessive production of waste and its disposal, working with the concept *cradle to cradle*, which consists of making the waste generate a new product.

Among the fashion products is the accessories sector, with eco-jewellery standing out as sustainable. Jewellery has been present since the beginning of humanity, carrying not only aesthetic value but also esoteric values. It is used as an amulet, a symbol of religiosity and protection, in addition to representing material wealth (Gola, 2021). Furthermore, in contemporary times, jewellery stands out as a strong sector.

Therefore, alternatives must be created for the use of diverse and more sustainable materials to obtain products that are ecologically less harmful to the ecosystem, thus promoting a balance between production, consumption, society and the environment. In the ideal circular economy model, materials must be returned to the production cycle through reuse, reduction and recycling, targeted awareness and promoting ecological attitudes.

In this way, contemporary jewellery emerges as an environment for free creation and experimentation, in which the use of unconventional materials is responsible for providing aesthetics, exclusivity and innovation, contributing to the economic appreciation of the piece.

3 COMPOSITE MATERIALS AND MDF

According to ASTM D3878 (2024), composites are materials made up of at least two components of different nature and are divided into a continuous phase, called matrix (consisting of metal, ceramic or polymer), and a dispersed phase, also called reinforcement, as it corresponds to the material that acts as a reinforcing agent (particles, fibres or sheaths), which can be organic or inorganic in nature.

Silva and Oliveira (2021) highlight that the correlation between eco-composites and the development of new products has progressively strengthened as new research is carried out, highlighting not only the growing environmental awareness, but also the effectiveness and viability of these materials in innovation of products in different sectors.

There is also a significant increase in interest in renewable materials and by-products to reduce dependence on petroleum-derived resources, as highlighted by Lopez *et al*. (2020). In this context, Zaaba and Ismail (2019) emphasise that this interest has emerged in recent years and that it aims to improve mechanical properties from an environmental perspective, notably through the use of organic waste.

3.1 POLYMERIC MATRICES

The composite material is generally composed of one or more discontinuous phases distributed in continuous phases. In the case of several discontinuous phases of different natures, the composite is said to be hybrid (Ahmadijokani *et al*., 2020). The polymeric matrix can be thermoplastic, thermosetting and/or elastomer. The role of the matrix is to connect the reinforcing fibres, distribute the restrictions, provide the chemical resistance of the structure and give the desired shape to the final product (Arabpour *et al*., 2020; Zheng *et al*., 2019). Furthermore, the choice of this matrix depends on the intended use of the composite material (Hsissou *et al*., 2021).

The main polymeric matrices are formed by resins, with the main polyester, phenolic, silicone, polyamide and epoxy. This last one, even having one of the highest costs, it is the resin most used by the industry (Gama, 2017). The matrix and reinforcement can be metallic, ceramic or plastic, which allows for an infinite number of combinations (Cheng; Jiang; Li, 2020).

The nature of the matrix and filler, the shape and proportion of the filler, the quality of the interface and the production process used are all parameters that can influence the properties of the composite material (Nagarajan *et al*., 2019; Zhou *et al*., 2019) and, in addition, the insertion of reinforcements with good tensile strength, with very high modulus in polymer matrix, allows improving mechanical and thermal qualities (Datsyuk *et al*., 2020).

3.2 POLYMERIC COMPOSITES REINFORCED WITH NATURAL FIBERS

Because they come from renewable and biodegradable sources, in addition to being more economically accessible and having a less negative environmental impact, natural fibres have gained the attention of the scientific community. They show initial degradation between 200-220ºC and are considered suitable for reinforcing polymers that are processed within this temperature limit, such as polypropylene (PP), polyvinyl chloride (PVC), low-density polyethylene (LDPE) and epoxy resins (Campbell, 2020).

Natural fibres are classified as vegetable, animal and mineral fibres depending on the source of extraction. These natural fibres are used as reinforcement based on application in polymer matrices to form bio-based composites and polymer composites (Mazzanti *et al*., 2019). Composites reinforced with natural fibres derived from plants such as hemp, flax, jute, kenaf, sisal, coconut, and bamboo, which are light, durable and efficient, have desired mechanical and physical characteristics and serve as an alternative to other conventional materials (Ramachandran *et al*., 2022).

Natural fibre-reinforced polymer composites (NFPCs) derived from renewable resources are environmentally friendly and also comprise a combination of natural fibres integrated with synthetic polymers derived from petroleum resources or biopolymers derived from natural or other renewable resources (Vinod *et al*., 2020). This use provides when compared to non-degradable fibres, a material with good mechanical and thermal properties, high tenacity and a lower cost (Pickering; Efendy; Le, 2016).

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As for elasticity, the modulus of elasticity is one of the most important parameters when choosing the most suitable fibre. Although natural fibres only have half the level of elasticity of glass fibres, the fact that they have a lower density allows them to have similar levels of specific resistance.

The abundant agricultural/industrial waste promoted by modern technologies has proven to be a barrier to sustainable development. Composites reinforced with natural fibres have been identified as a potential substitute in several applications due to their availability, cost-effectiveness, non-toxicity and biodegradability. Furthermore, these composites have excellent properties, such as high strength and stiffness, which make them an excellent alternative to glass or carbon fibres for high-strength applications, which are seen, for example, in constructions (Peças *et al*., 2018). Various natural fibres have been used to manufacture composites, such as jute, coconut, sisal, pineapple, ramie, bamboo, banana, hemp, bagasse, coconut, flax and curauá (Gholampour; Ozbakkaloglu, 2019; Singh *et al*., 2020).

Hard (2013) showed that composites reinforced with natural fibres of linen and sisal, due to their mechanical properties of flexion and traction, can be used in civil construction and the automobile industry, while Silva (2014) observed that the addition of jute fibre to the polymer matrix (epoxy resin), in a limited percentage, presents a satisfactory result in replacing conventional products used in these areas.

3.3 SUGARCANE

Practised since colonisation, the cultivation of sugar cane is of great importance for the Brazilian economy, being an activity carried out throughout the national territory, mainly in the state of São Paulo and in the Northeast region. This importance is due to the number of materials produced from this raw material, such as sugar, cachaça, ethanol, energy, rapadura (a sweet made of sugarcane), sugarcane juice and their by-products (Oliveira, 2018). According to the National Supply Company (Conab, 2021), Brazil is the largest producer of sugar cane in the world, whose 2020/21 harvest generated 654.5 million tons, which were destined for sugar (41.2 million tons) and ethanol (29.7 billion litres) production.

Bagasse, a residue obtained through the last grinding, is formed by lignocellulosic fibres composed of 2% silica, 19.95% lignin, 24.5% hemicellulose, 2.4% ash, 3.5% greases and fats, 46% cellulose and 1.7% other elements (Mulinari *et al*., 2009). It is considered the residue from the largest-scale agroindustry and has the greatest energy potential in Brazil, being mostly used to supply energy to the plants themselves (Unica, 2019).

However, the unused part of this waste has caused environmental impacts and storage problems, making new areas of application necessary (Benini, 2011). Several authors began research into other applications of sugarcane bagasse, which could serve as a component for the civil construction industry (Ganesan; Rajagopal; Thangavel, 2007), be used in the manufacture of automotive components (Luz; Caldeira-Pirez; Ferrão, 2010) and act as reinforcement in polymer composites (Benini, 2011; Mulinari *et al*., 2009; Oliveira, 2018).

Iwakiri (2005) defines MDF as panels produced from pressed wood fibres and bonded with synthetic resin, with urea-formaldehyde being the most commonly used. Among its main advantages are its low cost and versatility, as it can be found raw, painted, or coated, besides its mechanical properties, which makes it like solid wood. Furthermore, many consider it to be an ecologically correct product, as it is produced using reforested wood, not contributing to deforestation.

Araújo (2012) highlights that their biggest problem is their use in indoor environments, as they are responsible for a high concentration of formaldehyde vapour, causing discomfort, irritation and even greater health problems due to their carcinogenic and mutagenic potential.

4 MATERIALS AND METHODS

4.1 MATERIALS

The material used to produce the mold was silicone, with sugarcane bagasse fiber (2 mm), epoxy resin RP 031, Hardener RE-042R, Release Agent Vaseline and translucent blue dye 0212B003 for the manufacture of the composite.

Epoxy resin was selected due to its characteristics, as, among its advantages, it has low viscosity, high mechanical resistance, low volatility during curing and low wrinkling, in addition to a reduction in shear stresses (Gama, 2017).

In research carried out on several brands that sell these accessories, compositions were found with 100% polyester resin, polyamide, acrylic and even polyurethane. With the development of research, the aim is to reduce the amount of thermoplastic resin applied in the production of these materials used in accessories in fashion design as long the properties of resistance, flexibility, and liquid absorption, among others, are maintained within standards required by current regulations.

4.2 METHODS

4.2.1 PREPARATION OF SUGARCANE BAGASSE

After collection, the sugarcane bagasse residue was taken to an oven to dehydrate at 50ºC for 24 hours. It was then crushed in a mill with a 2 mm comb.

4.2.2 COMPOSITE MATERIAL PRODUCTION

Hand lay-up associated with the molding technique in silicone molds was the method chosen for the development of the composite material. It is a manufacturing process with manual application of the composite mixture (matrix and reinforcement) in an open mold widely used in the production of fibrous composites (Lin; Zhang; Zhang, 2023). As it is a manual technique, it has a low cost and is used in the production of a few parts.

The material samples were produced using a mixture of RP-031 epoxy resin with sugarcane bagasse fibre in different volumetric ratios, based on the work of Sampaio (2021). The percentages were defined: Sample 1 (A) -100%, 0% fibre; Sample 2 (B) -70%, 30% fibre; Sample 3 (C) -60%, 40% fibre; It is Sample 4 (D) -50%, 50% fibre.

4.2.3 LIQUID ABSORPTION AND SWELLING BY IMMERSION

The rate at which the material absorbs liquid when immersed is determined in the absorption test. Thus, an adaptation of the ASTM D570-98 standard (ASTM, 2010) was carried out, in which distilled water was replaced by saline, considering that it has a composition closer to human sweat. The samples have a rectangular shape and were produced in a silicone mold.

Four samples of each fibre percentage were developed: 0%, 30%, 40% and 50%, resulting in 16 (sixteen) specimens. Samples were measured with a digital caliper and taken to a drying and sterilisation oven at 50°C for 24 hours, all pieces were weighed and immersed in saline solution, also for 24 hours. Finally, they were removed from the serum, cleaned with absorbent paper to remove moisture from the surface, measured and weighed again to determine the absorption and swelling index.

To calculate the percentage of liquid absorption, the Equation1was used, where W1 is the initial weight of the sample (g) and W2 is the weight of the sample after immersion for 24 hours.

$$\% \text{ mass absorption} = W2 - W1$$
$$W1 \times 100$$

4.2.4 SWELLING TEST

The thickness swelling test provides the linear increase in material thickness. It was carried out adapting the NBR 14810-2 standard (ABNT, 2013), in which the maximum percentage increase allowed after 24 hours is 16% over the initial percentage. Thickness measurements were taken in the centre of the samples using a digital caliper.

To calculate the swelling in thickness, Equation 2, where the swelling in thickness (%), E0 is the initial thickness of the sample (mm) and E1 is the thickness after immersion for 24 hours.

$$I = E1 - E0E0 \times 100$$
$$xx$$

4.2.5 IMPACT TEST

The test was carried out on the IZOD impact machine with a 2.75 J pendulum and the samples were developed in rectangular format adapted to ASTM D256 (2018).

4.2.6 DEVELOPMENT OF THE ECO JEWELLERY COLLECTION

The conceptual creation of the collection was developed based on the Brainstorming tool. The term Brainstorming means “storm of ideas” and was created in 1939 by Alex Osborn and is currently available in the Asian Productivity Organization – APO Tools and Techniques Manual. It is a very versatile tool whose main objective is to stimulate the creation of as many ideas as possible in a short space of time and with low-cost materials. Furthermore, it consists of two phases (Young, 2020).

5 RESULTS AND DISCUSSION

The production of composite material samples and the presentation and analysis of the results obtained from the tests carried out are presented here. Then, the characteristics of the samples are compared with those of the MDF to establish the best composition of composite material to be used for the development of eco-jewellery.

5.1 PRODUCTION OF COMPOSITE MATERIAL

Samples were produced using the hand lay-up technique with different percentages of fibres: 0% bagasse/100% resin (control sample), 30% bagasse/70% resin, 40% bagasse/60% resin, and 50% bagasse/50 % resin. Figure 2 shows some stages of the sample production process.

5.2 IMMERSION LIQUID ABSORPTION TEST

The result of the absorption test can be analysed in Graph 1. A greater weight gain is observed as the percentage of fibres in the composition of the composite material increases. Therefore, sample A (100% resin), as it does not contain fibre in its composition, has the lowest liquid absorption rate (0.19%). When analysing the behaviour of the samples, it is noticeable that samples A, B and C show a gradual increase in their absorption rates in terms of weight, while the difference between samples C and D is more significant in relation to B, taking into account as they have a greater number of fibres in their composition.

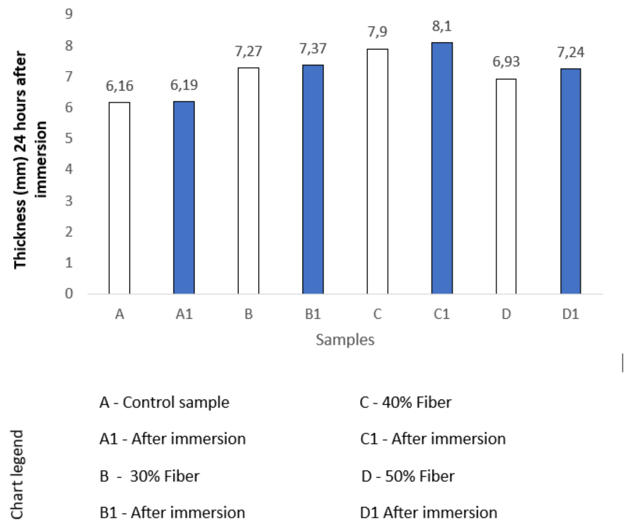

Figure 1 – Results obtained in the liquid absorption test by immersion
Fonte: Elaboração própria (2024).

In this way, it is possible to determine that sample B (30% fibre/70% resin) is the one that presented the best result, as it has the lowest absorption rate among the fibre samples, presenting only a 0.61% difference between the weighing results before and after the 24-hour immersion period. The sample that presented the worst result was D (50% fibre/50% resin), having the highest absorption rate, 8.40%. Thus, sample B presents an excellent result when compared to MDF, as, according to the ABNT NBR 15326 – 3 (2009) standards, the maximum absorption percentage for MDF is 40%.

The results corroborate the findings of the study by Chen *et al*. (2021), in which it is observed that liquid absorption in an epoxy resin composite with sugar cane bagasse increases proportionally according to the amount of fibre added. This results in a greater incidence of amino acid groups that interact with water molecules.

5.3 SWELLING TEST

Wondmagegnehu (2023), in his study, observed that the swelling in thickness of the composite increases with increasing immersion time until saturation occurs, as well as increasing with the percentage of sugar cane bagasse, which is in line with the results of this research. Figure 2 displays the results of the swelling test, and it is possible to observe an increase in thickness as the percentage of fibres in the composition of the composite material increases. Thus, sample A (100% resin), as it does not contain fibre in its composition, has the lowest swelling rate (0.49%).

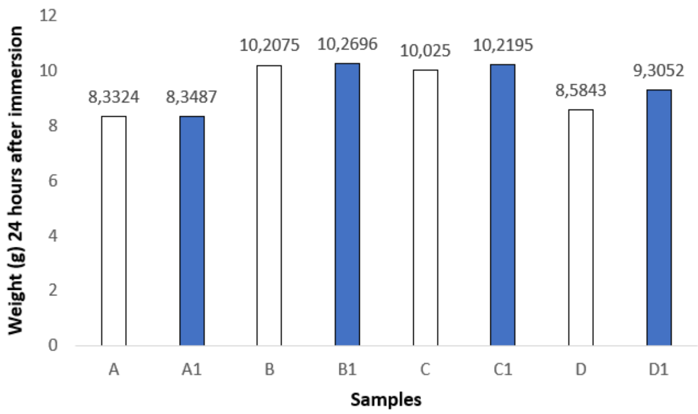

Figure 2 – Results obtained in the thickness swelling tes

Source: Farias (2021).

In this way, it is possible to determine that sample B (30% fibre/70% resin) is the one that presented the best result, as it has the lowest swelling rate among the samples with fibre, a rate of 1.37%, which resulted from the difference in sample thickness before and after the 24-hour immersion period. The sample that presented the worst result was D (50% fibre/50% resin), having the highest swelling rate, 4.46%. Therefore, when compared to MDF, sample B presents an excellent result, as, according to the ABNT NBR 15326 – 3 (2009) standards, the maximum swelling percentage for MDF is 12%. The swelling percentage results can be seen in Table 1:

Table 1 – Percentage of swelling

SAMPLES	*INITIAL THICKNESS (E0)*	*FINAL THICKNESS (E1)*	IMCHALLATION (I)
A (0% fiber)	6.16mm	6.19mm	0.49%
B (30% fiber)	7.27mm	7.37mm	1.37%
C (40% fibre)	7.9mm	8.1mm	2.52%
D (50% fiber)	6.93mm	7.24mm	4.46%

Source: Farias (2021).

5.4 IMPACT TEST

Prasad *et al*. (2020) highlights that the maximum impact energy was observed for the composite reinforced with the highest percentage of fiber in the mixture with the resin, which also reinforces the ductile nature of the fiber. The result of the impact test carried out here can be analysed in Figure 3, in which it is observed that the greater the energy expenditure in joule (J), the greater the resistance of the material. Thus, the control sample (100% resin) was the one that presented the highest energy expenditure, 18.1116 J.

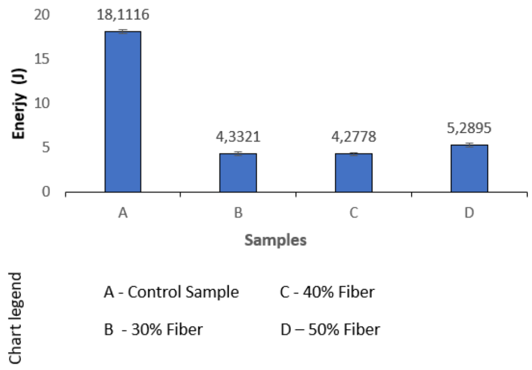

Figure 3 – Results obtained in the impact test

Source: Farias (2021).

The sample with a percentage of fibre that presented the best result was sample D (50% fibre), with an expenditure of 5.2895 J and greater impact resistance. The sample with the worst result for the impact test was sample C (40% fibre), showing the lowest energy expenditure, 4.2778 J. However, sample C did not show such a high variation compared to sample B (30% fibre), with a difference of 0.0543 J. All samples obtained a superior result compared to commercial MDF tested by Prioli, Palma and Moraes (2019), which presented a result of 3.74 J for the 3 mm thick MDF sheet.

5.5 CHOOSING THE BEST COMPOSITE MATERIAL SAMPLE

The analysis of all laboratory test results is now presented to determine which sample of the developed composite material has the best result for the objectives of this work. The requirements to be evaluated are sustainability and durability/technical aspects (test results), which are shown in Table 2, completed using a Likert scale from 1 to 5 (1—very bad and 5—very good).

Table 2 – Selection matrix for the best composite sample

REQUIREMENTS	*SAMPLE 100% RESIN*	*SAMPLE 30% FIBER*	SAMPLE 40% FIBER	SAMPLE 50% FIBER
Sustainability (incorporation of waste - fiber)	1	3	4	5
Liquid absorption	5	4	3	two
Thick swelling	5	4	3	two
Impact resistance	4	two	two	3
Final grade	3.75	3.25	3.0	3.0

Source: Farias (2021).

Sustainability is an important requirement. And, although all samples have the potential to replace MDF, as it is clear that the higher the percentage of sugarcane fibre bagasse, the greater the sustainable character of the composite, it is necessary to analyse the test results. It is observed that samples with a lower percentage of fibre obtained better performance for the absorption and swelling tests, while for the impact test, the higher the percentage of fibre, the greater the resistance of the composite.

Therefore, it can be concluded that, according to the method used to select the best sample, B (30% sugarcane bagasse/70% resin) exhibits the best performance for the applicability of this work. Despite this, this conclusion does not exclude the possibility of using samples C and D, as they presented equal results in the selection procedure used, as well as results close to those of sample B, selected first.

6 PRODUCT DEVELOPMENT

The conceptual creation of the proposed collection was developed based on the Brainstorming tool, carried out after choosing the theme and used in the production of the inspiration panel. New perspectives for the future require reconnection with nature and the search for a healthier and more sustainable lifestyle. In this context, these were the inspirations that gave the beginning and basis for the development of Brainstorming, for the creation of sustainable products and for the appreciation of local culture, highlighting the Poti and Parnaiba rivers, in addition to the riverside landscape of the city of Teresina, Piauí, Brazil.

The macro trend used to develop the collection was Natural Minimalism, which involves the connection with good energy, coziness, rusticity and lightness, which are worked on in handcrafted pieces using a mix of materials, ranging from more organic and fluid forms to natural stones combined with metals.

6.1 TARGET AUDIENCE

The amount of information that is easily accessible today is a way of disseminating not only trends, but lifestyles and concepts, interacting with consumers, raising awareness of concerns about the planet and the impacts generated for future generations, which they have more ethical thinking (Albuquerque, 2022).

Bauman (2001) states that modernity is liquid and identity is created by consumption, in which modern man is in the eternal search for the new, for satisfaction and freedom. In this context, eco jewellery is aimed at a female audience with a higher purchasing power that values the local culture of Teresina and the creation and consumption of sustainable products with a delicate and differentiated design.

6.5 RIBEIRINHOS REFLECTIONS COLLECTION

Fountains and watercourses in ancient times were symbols of prosperity and abundance and exhibited a sacred character that inspires spiritual practices perpetuated to this day. Hail (1999) says that the dynamic movement of these watercourses alludes to the renewal and continuity of life, in which the river and its banks are the connection between the natural environment and man.

According to the National Water Agency (Araújo, 2023), the city of Teresina-PI is surrounded by the rivers that run alongside the city, which are Parnaiba and Poti rivers. The meeting of the rivers is one of the most visited tourist attractions in the city, as they come along together, drawing the border between the states of Piauí and Maranhão and becoming a single riverbed that migrates towards the Atlantic Ocean. Furthermore, the region is a cultural heritage that is related to symbolic, affective, economic, environmental and cultural issues (Farias, 2018).

The inspiration panel has the function of assisting in the design process of the pieces, as well as in the choice of materials, textures, colors and shapes. Its development was guided by the local landscape, craftsmanship and rivers and their mysteries. The collection called Reflexos Ribeirinhos represents the duality of the two rivers, whose immensity of their waters reflects the mysteries they hold, framing the local riverside landscape and undoing the rigidity of the city as it approaches the nature, the banks, and the fluidity of the waters. So, based on this concept and the inspirations in the panel, a collection was created consisting of fourteen pieces, four earrings, four necklaces, a body chain, three bracelets and two rings.

The elements chosen and presented in the collection are shapes, colours and textures. The concept is worked into the pieces through the duality of shapes, in which the delicacy of the silver thread is a counterpoint to the rigidity of the composite material developed. In the collection, the composite was dyed with a translucent blue dye, and the bagasse fibres were visible, reminiscent of the mysteries that rivers hold. The choice of natural stones and their colours represent the richness and abundance of nature, and, in addition, the organic shapes of the elements refer to the flow of water.

6.3 PRODUCTION OF PROTOTYPE PARTS

At this stage of the work, two pieces from the collection were made, being produced with the composite material 30% bagasse/70% resin, i.e., with sample B, to prove that the proposed material is applicable in an eco-friendly jewellery collection.

The materials chosen to harmonise with the developed composite were:

- Silver 925 and 950 - used in the jewellery industry in the state of Piauí;
- 950 silver wire - is a malleable and delicate material made from silver scraps, a more sustainable bias;
- Natural stones - freshwater pearl, rose quartz sphere, amethyst faceted sphere, red jade and green jade.

With the models selected, the sheets were created techniques. The pieces were produced manually and laser-cutted. The natural stones and welding of the chain to assemble the necklace were carried out by a local designer. The first stage was the development of the composite material dyed with blue dye on a 3mm sheet and laser cutting into the proposed formats. Next, the algae were made from twisted silver threads, natural stones and silver canutilils. Finally, the jewellery was finished with silver pieces: chain, rings, pins, screws and close. Figure 1 shows the result of the pieces of the collection called Reflexos Ribeirinhos.

Figure 4 – Earring and necklace in 950 silver wire, natural stones and composite material
Source: Farias (2021).

The collection's proposal was achieved. The 30% fibre/70% resin composite material had excellent performance, as it had the ability for laser cutting without damage and was compatible with dyeing and the incorporation of silver parts. In this way, the feasibility of applying the material in the proposal to create an eco-friendly jewellery collection is proven.

7 CONCLUSIONS

This work aimed to develop a sugarcane bagasse-reinforced composite material to replace MDF in eco-friendly jewellery applications in a sustainable way. This material was subjected to laboratory tests for liquid absorption, swelling and impact to prove its applicability in the proposed area. Production was carried out using the hand lay-up technique, which proved to be satisfactory. Furthermore, it was observed that the greater the number of fibres in the composition, the more difficult it was to get it homogeneous and without bubbles or flaws, with the main factor being the characteristics of the sugarcane fibre crushed to 2 mm.

Through laboratory tests, it was possible to analyse the behaviour of the composite material obtained. With the liquid absorption and swelling tests, it was observed that the best results were those of samples with a lower percentage of fibres since the higher the percentage of sugarcane bagasse fibres, the greater the absorption of liquids and, consequently, the greater the swelling in thickness of the samples.

Finally, with the impact test, it can be concluded that the addition of sugarcane bagasse reduced the impact resistance of the composite compared to the control sample (100% resin). However, it is possible to notice that, in the analysis of fibrous samples, the increase in the number of fibres contributed to the increase in the strength of the composite since the 50% fibre sample presented a better result than the 30% and 40% fibre samples.

At the end of the tests, a comparative study was carried out between the developed composite and MDF, and it was assured that the manufactured material meets the requirements for application in eco jewellery. Furthermore, the work presented does not rule out the use of materials with the highest percentages of fibre, and, as a result, this research opens a path to new studies and new possibilities for applications of this type of material in the fashion industry.

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