


Chapter 20

Biotechnology applied to the buriti fruit (*Mauritia flexuosa* Mart.)

 <https://doi.org/10.56238/methofocusinterv1-020>

Zilmar Timoteo Soares

Biologist, Master and Dr. In Education. Adjunct Professor IV, State University of the Tocantina Region of Maranhão - UEMASUL. Pro-Rector of Extension and Student Assistance

E-mail: zilmar.soares@uemasul.edu.br

Amanda Araújo Nascimento

Graduated in Geography (UEMASUL/) Coordinator of Regional Development and Citizenship/CORDEC/ at The Pro-Rector of Extension and Student Assistance - PROEXAE at UEMASUL

E-mail: amanda_nasci@hotmail.com

Veronica Santos da Silva

Graduated in pedagogy from UEMASUR, head of university extension division at UEMASUL DIVEXT
E-mail: veronicasilva.201770237@uemasul.edu.br

ABSTRACT

Plastic has environmentally unfavorable factors. First, it is about its origin, coming from petroleum, a non-renewable source, hydrophobic materials that do not allow the action of microorganisms in its molecular chain, taking hundreds of years to decompose. In this sense, there is the buriti palm whose fruit is rich in natural polymer, which can be produced a biodegradable plastic, due to its organic characteristic, which decomposes easily and quickly causing without damage to the environment. With that, the. The objective of this research was to develop a flexible, biodegradable bioplastic based on natural polymers from renewable sources from the epicarp, mesocarp, buriti fruit endocarp and cassava starch by cooking process. Initially, a dimensional characterization of the buriti fruit was carried out with 120 individuals. Elaboration of different bioplastics with buriti fruit

matrix in 90, 95 and 98% associated with cassava starch in 2, 5 and 10%, plasticized with glycerol. The characterizations of bioplastics were carried out through the evaluation of subjectivity, thickness, mechanical properties, opacity, color, water solubility, temperature resistance test, chemical resistance and biodegradation in water and soil. All bioplastics formed were visually transparent in 80% and opaque in 20%. With the increase in the addition of cassava starch, it caused an increase in thickness, permeability to water vapor and tensile strength, generating a decrease in their opacity. In evaluating the subjectivity of the samples, homogeneity was around 88.53%, flexibility 80% and deformation 8.6%. In the strength tests, the epicarp bioplastic showed low elongation (91.20 Mpa), while the endocarp showed greater elongation (4.41%) and low strength (42.50 Mpa). As for the evaluation of opacity, the endocarp exhibited a larger radius of 1.72cm, while the smallest length was manifested in the bioplastic epicarp 0.63cm. The bioplastics were subjected to temperatures of 60, 80, 100, 110 and 120°C, and in the first temperatures they remained at normal levels, from 100°C onwards, curvatures, dryness and cracks appeared. Based on these results, the concentrations of the mixture components were changed to allow the obtainment of decorative bioplastics, with adequate properties by the cooking process. Thus, it can be said that the production of composite bioplastics based on the epicarp, mesocarp and endocarp of the buriti fruit and added with cassava starch, plasticized with glycerol, by the cooking process is environmentally and economically viable.

Keywords: Bioplastic, Biodegradation, Natural polymers, Renewable sources.

1 INTRODUCTION

Plastic is a material whose fundamental constituent is a polymer, mainly organic and synthetic, solid in its final condition, as a finished product, and which at some stage of its production was transformed into fluid, suitable for molding by heat or pressure action (PIATTI *et. al.* 2005),

The demand for synthetic or plastic polymeric materials in society is becoming increasingly increasing, compared to in recent decades. For, these materials have functional properties, versatility and a low cost that favor their processing and use in various applications (FECHINE *et. al.*, 2011).

Despite all this, these materials present environmentally unfavorable factors. First, it is its origin, coming from oil, a non-renewable source, hydrophobic materials that do not allow the action of microorganisms in its molecular chain, taking hundreds of years to decompose (SANTOS *et. al.*, 2013)

Being that, these materials have a very fast disposal, causing a large accumulation in landfills and dumps (Franchetti *et al.* , 2006). Thus, the need to reduce the use of plastic materials has been recognized and their recycling is becoming almost an obligation for manufacturers and consumers, this process depends largely on the selective collection of the product and this does not reach all the recycling discarded in nature (LEITE *et. al.*, 1999).

So the following question is. Is it possible to produce a plastic using vegetable fibers of the buriti fruit that has rapid decomposition without harming the environment?

Starting from this assumption, the substitution of the conventional raw material used in the manufacture of such polymers by vegetable fibers, for example, has great potential to alleviate such impacts by the use of non-renewable sources. Thus, the fibers taken from the buriti fruit, which, in addition to strengthening the polymer, are biodegradable, have low cost, are light (due to their low density) and do not have abrasive characteristics, which facilitates their molding, is used as the object of study in this project. They come from renewable sources and have mechanical characteristics that tend to increase the properties of polymers that were added with them (BALZER *et. al.*, 2007, p. 01).

The Buriti (*Mauritia Flexuosa*) is a species of palm tree of Amazonian origin, also known by the names of buriti-do-brejo, carandá-guaçu, carandaí-guaçu, coconut tree-buriti, itá, palm tree, buritizeiro, meriti, miriti, muriti, muritim, muruti (BARRO and JARDINE 2020).

It is predominantly found in the North region, but also appears frequently in the states of Maranhão, Piauí, Bahia, Ceará, Federal District, Minas Gerais and Mato Grosso. Known as one of the most beautiful palm trees, reaching between 20 m and 35 m high, the buriti develops on low ground with great water supply, such as riverbanks, swampy or permanently flooded areas, forming clusters of plants, called buritizais. For this, it is essential that the soil is acidic (BARRO and JARDINE, 2020).

The species called by indigenous peoples the "tree-of-life" is fully exploited by communities in extraction areas. It has fan-shaped leaves, coconut fruits and has a very slow growth, but has great longevity, since some types with more than 10 m can be between 100 and 400 years old (SOARES, 2020).

The coconuts are covered by scales of reddish-brown color, from 4 cm to 7 cm in length, 3 cm to 5 cm in diameter, with weight ranging from 25 g to 40 g each, consisting of hard oval seed and edible almond of yellow-orange color, bittersweet flavor and greasy consistency. This material can be used to remove a biodegradable polymer (SOARES, 2020).

Thus, this research has as its theme the search for a biodegradable plastic utilizing the fruit of the buriti that, due to its organic characteristic, which decomposes easily and quickly without causing harm to the environment.

ONE, I'M SORRY. 2 OBJECTIVES

The objective (general) of this research was to develop a flexible, biodegradable bioplastic based on natural polymers from renewable sources of the epicarp, mesocarp, buriti fruit endocarp and cassava starch by cooking process. As specific objectives: To characterize the fruit of buriti as an essential element in the development of sustainable biotechnology; Produce bioplastics using the epicarp, mesocarp and endocarp of the buriti fruit, with cassava starch additive; Characterize bioplastics in different evaluations; Test biodegradation of bioplastic in water and soil; Use decomposition residues as fertilizer in greenhouse plants; Create decorative bioplastic in different sizes.

TWO OF THEM. THEORETICAL FOUNDATION

2.1 NON-BIODEGRADABLE PLASTICS

In 1960, the English chemist Alexander Parkes began a great process of innovation in the world through the development of a pulp-derived product, parkesine (UFCG, 2017). The new material had very peculiar characteristics, such as flexibility, strength and impermeability, being known as a precursor material of current plastics (INNOVA, 2017; UFCG, 2017).

During the second half of the 20th century, plastics underwent a considerable evolution until they presented the current properties. Currently, we have a versatile, flexible, resistant and highly imposing plastic material Zanin & Mancini, (2015). In addition, the plastics used in today's industry have low production cost and provide greater durability figure 01, (ISA, 2005).

These characteristics justify the expansion of Brazilian production in the plastics sector, since the product was incorporated into people's daily lives. Using plastic in material manufacturing processes or for packaging products is one of the stages of the production chain in Brazil and clearly demonstrates the importance of this material to society (BARBOSA & CAMPBELL, 2015).



2.2 DAMAGE TO THE ENVIRONMENT CAUSED BY PLASTICS

Although the consumption of plastics is often inevitable, its exaggerated practice is responsible for generating large volumes of waste that are harmful to the environment and, consequently, become a socio-environmental and public health problem. The environmental problems caused by it can be easily found in any environment figure 02, whether in urban area or in a natural environment (QUEIROZ, 2010).



2.3 THE SEARCH FOR ALTERNATIVES TO NON-BIODEGRADABLE PLASTICS

Every day, greater emphasis has been placed on the preservation and conservation of the environment as a way to ensure sustainable development and the quality of life on planet Earth. Thus, in the midst of so many negative consequences due to the inappropriate use and disposal of non-biodegradable common plastics, a search for alternatives for the product that were economically and environmentally viable began (CARASHI & LEÃO, 2002).

One of the alternatives found was the elaboration of a product with polymeric properties similar to plastic (figure 03), but produced from renewable sources and less aggressive to the environment, bioplastics (SANTOS et al., 2013; RODRIGUES et al., 2015; RUDIN & CHOI, 2016).

This new product has been seen as the green solution of the future, because it has as advantages the possibility of large-scale production, low cost and the shortest time of degradation of the product and, consequently, be environmentally sustainable (OLIVEIRA et al., 2021).

Objects developed from bioplastic



Source: <https://viverforadosistema.org.br/>

2.4 STARCH-BASED BIOFILMS

Among the biodegradable films produced from polysaccharides, starch-based films figure 04 stand out, because they are an alternative to traditional resins that are economically more viable and because they originate from widely available and available renewable sources and low cost Souza (2011). In addition, they have the ability to form a continuous matrix with low oxygen permeability and produce transparent films, free of odor, color and flavor (JIMÉNEZ et al., 2012).

Thus, many researchers have investigated different ways to improve the properties of starch-based films. Some of them report changes in properties when using different sources of starch, such as peas, potatoes, rice, cassava, corn and modified starches and different plasticizers. Other authors have evaluated the improvement of the properties of starch films from the mixture with other polymers (MORAES, 2009).



2.5 BURITI FRUIT

The buriti fruit (figure 05) has a shape that goes from elliptical to oval, surrounded by a pericarp (bark), containing triangular scales and reddish-brown color. The mesocarp (mass) is thin and the color varies from yellow to orange, very carnosous and oily. The endocarp (bushing) consists of a spongy, slender fabric, which goes from white to yellowish, with a high cellulose content and low density. The endosperm (seed) is very hard, ovoid in shape, having an average of 2.5 cm in size, which occupies most of the fruit volume. The pulp has 20 times more vitamin A than carrots, a food that is a recognized source of this vitamin (SAMPAIO; CARRAZZA, 2012).

The fruits vary in size, color and shape, and due to various uses can be marketed by different denominations. Regardless of morphology, the pulp contains high concentrations of vitamin A and carotenoides. It can also be used in food preparations which prevents, for example, xerophthalmia (a disease characterized by non-tear production and vision difficulties, especially during the night). It is rich in vegetable oil which allowed to be used in different ways in industries (BARBOSA; FILE; JUNIOR, 2010).



2.6 GREEN BIOTECHNOLOGY APPLIED IN FILM PRODUCTION

The biotechnology of films is obtained from the physical incorporation of cellulose nanoparticles to polymeric matrices figure 06. The properties of these nanocomposites depend on the characteristics of the added cellulose nanoparticles, the polymer matrix, the interaction between both and the Molina processing techniques (2013). Several authors have evaluated the effect of the incorporation of different sources of cellulose nanoparticles on the properties of biodegradable films and, despite the challenges existing in this area, the studies presented in the literature have obtained significant advances and the use of materials on a nanoscale has been shown to be promising.

Due to the nanometric size and crystalline, the addition of coconut fiber nanocellulose to cassava starch also showed positive results, significantly altering the mechanical properties, water activity and solubility, with the formation of a homogeneous film. An increase in the Young module and in the maximum traction and decrease in solubility and water activity were observed. Analyses were performed in CSD and TGA to evaluate the mechanical stability of the films after 90 days of storage and the results indicated that the mechanical properties were not significantly altered (MACHADO et al., 2014).

Cassava starch films plasticized with polyvinyl alcohol and added bamboo nanofibers also had their tensile strength and tension properties improved, with an increase of 24 and 51%, respectively. Water vapor permeability decreased by 20% and solubility by 30%. However, the addition of the reinforcement reduced the elongation by 40% in relation to the control and the transparency of the films (GUIMARÃES JR. et al., 2015).

With all this technical information, it was observed that it is possible to develop a bioplastic using the epicarp, mesocarp and endocarp of the buriti fruit, since it is possible to find cellulose, hemicellulose and vegetable lignin nanoparticle.



3 MATERIALS AND METHODS

This is scientific research with experimental focus. According to Fonseca (2002, p. 11-2) Experimental research is characterized by directly manipulating variables related to the object of study and aims to test hypotheses that concern the conviction of those who are researching.

The experimental research, notable for its contributions to the development of physical and biological sciences, as well as the recognition of the influence of the interaction of several factors on the final result of any phenomenon, where the experimental method is used to understand these phenomena Green, (2018).

In order to test the hypotheses, the fruit of buriti (*Mauritia flexuosa*) was chosen, with the possibility of transforming it into a biodegradable plastic.

3.1 RAW MATERIAL (BURITI PALM FRUIT)

The raw materials used in the elaboration of biodegradable plastics (bioplastic) were epicarp, mesocarp and endocarp powder of the buriti fruit obtained in the central market of the city of Imperatriz Maranhão (figures 07), buritizais veredas in the municipalities of João Lisboa Maranhão and Ananás Tocantins (figure 08).



The fruits acquired on the buritizais's veredas were collected under the palm tree after maturation when they fall, figure 09. Only 60% of the fruits were collected, the other 40% serves as food for birds, monkeys and small rodents, which feed on the pulp and then release the pit that will give rise to a new palm tree.

After collection, the fruits were sanitized under running water, stored in a cardboard box and transported to the laboratory. In the laboratory they were conditioned in small buckets and taken to the freezer for 36 hours before the pulping process.



3.2 DIMENSIONAL CHARACTERIZATION OF BURITI FRUIT

For the dimensional characterization of the buriti fruit, 120 specimens were randomly selected to measure weight, length, diameter and circumference. In this process, a caliper, measuring tape and a Bioscale model precision scale were used. The measurements were performed in five positions along the fruit. In each position, a second measurement was obtained by turning the fruit 90 degrees and considering the average of the two positions. This procedure was adopted due to the fact that the straight section of the fruit is not perfectly circular. That is, in every fruit there is an eccentricity in the diameter.

3.3 PULPING OF THE FRUIT

For the removal of the buriti fruit pulp, the following materials were used: a faca Tramontina with the precise cutting of the stainless steel blade and perfect ergonomic handle in polypropylene, with dimensions 27.5 x 4 x 1.0 cm. A stainless steel fork. Kit of 3 stainless steel sieves for sing pulp. Santana casserole iron pan with capacity for 300 ml. Blender, BLP50, Brushed Steel, 220v, 900W, Electrolux. For pulping the fruits were removed from the freezer and placed in the iron pot and warm water was added at 60°C. After one hour with the aid of the knife and fork, the bark (epicarp), the pulp (mesocarp) and the endocarp (seed film located between the pulp and the pit) were removed to dry in the sun. After dry they were crushed in a blender (figures 10 and 11).



3.4 TECHNOLOGY APPLIED IN THE PREPARATION OF BIOPLASTIC

In the execution of the project, two technologies were applied, nanotechnology and biotechnology. The importance of nanotechnology in the development of this research is due to the fact that the nanoparticles of the epicarp, mesocarp and endocarp of the buriti fruit when they spread at the time of bioplastic production do not contaminate the environment. Thus making it an innovative process.

Thus, the Nanoparticles used in the development and production of biodegradable materials aim to increase efficiency in the structure, reducing costs and increasing productivity.

Biotechnology, on the other hand, provides the development of technologies based on biomolecular and cellular processes, to create or modify products and solve problems in society while preserving life. With this context, it was achieved from the buriti fruit to manufacture a plastic and biodegradable utensils.

3.5 BIOPLASTIC PREPARATION USED THE POWDER OF THE MESOCARP EPICARP AND ENDOCARP OF THE BURITI FRUIT WITH THE ADDITION OF CASSAVA STARCH

The equipment and reagents used for the preparation of biodegradable film were: iron pot, PV spatula, glass plate, granulated epicarp powder, fine mesocarp powder and buriti fruit endocarp powder, cassava starch (tapioca purchased at empress fair), cassava acetic acid and glycerol.

Fifteen formulations were performed, five of which were extracted from the study object. The different formulations can be observed in Table 1. After the formulations, they were analyzed in the following aspects: subjectivity; thickness; chemical resistance; mechanical properties; opacity; color; water solubility; temperature resistance test; biodegradation test in water and soil; residue elimination test.

The amounts of materials used, glycerol and cassava starch to be used were defined according to the values obtained in preliminary tests and quantities presented in the literature (MACHADO et al., 2014; SILVA et al., 2015).

Table 1 Proportion of the ingredients used for the preparation of the different biodegradable films.

| Samples | Matrix (g) | Additive(g) | Water | Glycerol | A. acetic | Cooking | Drying |
|---------|------------|-------------|-------|----------|-----------|---------|------------|
| 001 | 1.5/Pp | 0.5 A.M | 10ml | 2.5 ml | 1.5 ml | 3 mins | 3 :00 a.m. |
| 002 | 1.6/Pp | 0.5 A.M | 15ml | 2.5 ml | 1.5 ml | 3 mins | 3 :00 a.m. |
| 003 | 1.6/Pp | 0.6 A.M | 10ml | 2.5 ml | 1.5 ml | 3 mins | 3 :00 a.m. |
| 004 | 1.7/Pp | 0.6 A.M | 15ml | 2.7 ml | 1.5 ml | 4 mins | 4 hs) |
| 005 | 1.7/Pp | 0.7 A.M | 15ml | 2.7 ml | 1.5 ml | 4 mins | 4 hs |
| 006 | 1.5/Cs | 0.5 A.M | 10ml | 3.0 ml | 1.0 ml | 4 mins | 5 hs |
| 007 | 1.6/Cs | 0.6 A.M | 10ml | 3.0 ml | 1.0 ml | 4 mins | 5 hs |
| 008 | 1.6/Cs | 0.7 A.M | 10ml | 3.0 ml | 1.0 ml | 4 mins | 5 hs |
| 009 | 1.8/Cs | 0.8 A.M | 10ml | 3.0 ml | 1.0 ml | 4 mins | 5 hs |
| 010 | 1.8/Cs | 0.8 A.M | 10ml | 3.5 ml | 1.0 ml | 6 mins | 6 a.m. |
| 011 | 2.0/Ed | 0.9 A.M | 15ml | 3.5 ml | 1.5 ml | 4 mins | 6 a.m. |
| 012 | 2.0/Ed | 0.9 A.M. | 15ml | 3.5 ml | 1.5 ml | 4 mins | 6 a.m. |
| 013 | 2.6/Ed | 1.0 A.M | 10ml | 3.7 ml | 1.0 ml | 5 mins | 7 a.m. |
| 014 | 2.6/Ed | 1.0 A.M | 15ml | 3.7 ml | 1.0 ml | 5 mins | 7 a.m. |
| 015 | 2.6/Ed | 1.0 A.M | 15ml | 3.7 ml | 1.0 ml | 5 mins | 7 a.m. |

All formulations were elaborated with ingredients extracted from the pulp (mesocarp), bark (epicarp) and endocarp. Cassava starch was used as an additive.

Different measures were used to verify the final formulation of bioplastics.

Pp - Pulp powder. **Cs** - Bark, **Ed** - Endocarp, **A.M** - Cassava starch.

3.6 CHARACTERIZATION OF BIOPLASTICS IN DIFFERENT EVALUATIONS

3.6.1 Subjective assessment

Visual and tactile analyses were performed to verify whether the bioplastics obtained were homogeneous, flexible, uniformly colored, easily removed from glass plates and free of insoluble particles and bubbles.

3.6.2 Thickness of bioplastics

The thickness of the preconditioned films was determined using a caliper. Four measurements were performed at random positions of each specimen and the thickness was taken as the arithmetic mean of the measurements in 5 specimens for each formulation.

3.6.3 Chemical resistance of bioplastics

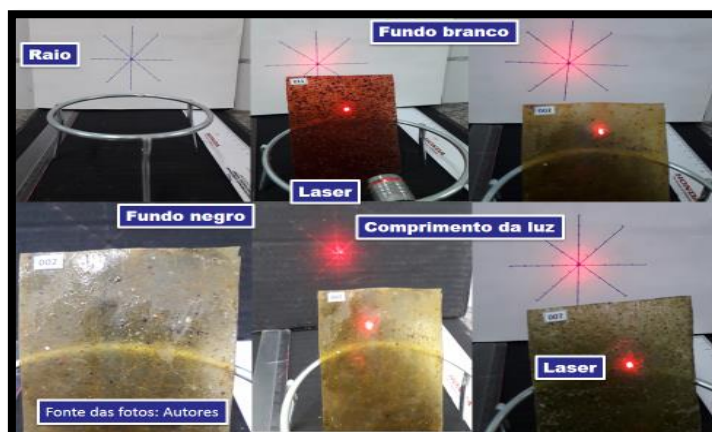
To evaluate the chemical resistance, small fragments were deposited in 50ml beques previously identified, and then immersed in soapwater, detergent, acetone and ethyl alcohol for 48 hours.

3.6.4 Mechanical properties

The mechanical properties of tensile strength (RT) and elongation (E) were determined using a texturômetro (Brookfield, ct3 model) with claws. We analyzed 15 rectangular specimens, 5 of each formulation, at a speed of 2 mm/s, firing force of 0.1 N and initial distance between the claws of 43 mm. Stretching was calculated using the following formula: $E = \frac{L - L_0}{L_0} \times 100$, where the result was given in percentage.

3.6.5 Opacity

Opacity (OP) was measured by the transmittance of light, using laser, adapted from the work of Santos et al. (2016). The amostras were cut into rectangles, placed vertically supported by an iron tripod and analyzed the length of the rays on a white background and black background figure 12.



The opacity was measured by the distance of the light focus in the two backgrounds with the following equation:

$$Op = Rfn/Rfb .100 \quad RF=Mr/100$$

Op - opacity. Rfn – bioplastic radius overlaps the black background. Rfb - bioplastic radius overlaps white background. RF - Final resulting. Mr - Average of the resulting

3.6.6 Color

Color analysis was performed on a portable calorimeter (HunterLab, Model MiniScan EZ 4500L) measuring the parameters L* (luminosity), a* (variation of the yellow tone) and b* (variation from yellow to red). The films were analyzed on a white plate.

3.6.7 Water solubility

The analysis of water solubility of the films was performed based on adaptation of the method proposed by Gontard. Initially, small sections of the dry films were weighed and then immersed in distilled water, kept under slow and periodic manual agitation at room temperature. The remaining film fragments were then removed from the bath and dried in a 100° greenhouse to determine their final dry mass. The calculation for solubility was performed according to the equation: $Pm = mi - mf/mi$

Where, Pm refers to the loss of mass, mi is the initial mass obtained at the first weighing and mf is the final mass.

3.6.8 Temperature resistance test

All bioplastic samples were placed in Petri dishes and subjected to stuff heating at different temperatures (20, 30, 40, 50, 60, 70 and 80°C) for 20 minutes to verify at what temperature the materials could present deformations. We consider deformations, the cracks that arose in the treatments. In relation to temperature, it is considered maximum of 80°C because, at a higher temperature the fragments began to burn.

3.6.10 Biodegradation test

For the water biodegradation test, 500ml of running water was added to all samples figure 17. The samples were weighed (epicarp 2.7g, mesocarp 2.1g and endocarp 1.1g) and placed in three beques, and the fragments of bioplastics of the epicarp 7 x 4 cm, mesocarp 5 x 4 cm and endocarp 5 x 4 cm were submerged for 15 days at room temperature and being monitored daily.

For the soil biodegradation test, 500 g of soil were added to all samples, collected in the 0-30 cm depth layer. The samples were weighed and placed in 3 trays of 40 x 20 cm (epicarp 2.9g, mesocarp 1.8g and endocarp 1.9g), and the bioplastic plates of the epicarp 7 x 4 cm, mesocarp 5 x 4 cm and endocarp 5 x

4 cm were weighed and buried in the soil and incubated for 20 days figure 17, at room temperature monitored daily.



3.6.11 Standards and certification of biodegradation

In addition to the delimited biodegradation time for the utensil to be considered biodegradable, it is necessary to follow some standards to be validated as a biodegradation material.

Some of these standards are the American ASTM 6400, 6868, 6866, however, based on ABNT NBR 1544-2, which regulates the process of biodegradation and composting. Laboratory tests and tests were required.

3.7 TESTING OF DECOMPOSITION RESIDUES IN WATER AND SOIL

The material of the decomposition of both water and soil were used as fertilizer in greenhouse plants to verify whether the material presented cleanness to the environment. This essay lasted 30 days and was followed every two days, where the result of the observation was noted in the field notebook.

3.8 CREATION OF DECORATIVE BIOPLASTICS IN DIFFERENT SIZES

After all the tests, different decorative bioplastics were produced, with the objective of producing bags and acrylic materials. This material was followed by the same bioplastic production parameters used in the initial tests, and increased the composition of the matrix and additive (cassava starch) according to the size of the required design. When the decoration was based on the flora of the cerrado, not to miss the original characterization of the project figure 18.



4 RESULTS AND DISCUSSION

Currently, the use of natural fibers as reinforcement in composites has great potential, replacing glass fibers and other materials, which will have an impact both in reducing the dependence on materials from non-renewable sources Araújo et. al., (2008), as with regard to environmental and economic aspects (RAMIRES et. al., 2010).

Brazil has a high potential for the production of natural fibers and produces a high number of different lignocellulosic fibers. The advantages of using natural fibers over traditional synthetic fibers (glass fibers) as reinforcement in composites are: plant fibers are produced from renewable sources, have low density, are not abrasive to processing equipment and are biodegradable (TOMCZAK et. al., 2014).

4.1 CHARACTERIZATION OF THE BURITI FRUIT

Table 02 shows the result of the buriti fruit (*Mauritia flexuosa*) analyzed, where they presented similar values for the characteristics of mass, length, diameters and circumference similar to the values found by Ribeiro & Soares (1999) and Morais & Dias (2001), for characterization of arecaceas species. The physical characterization of the raw material is essential to understand the behavior of the product in the formulation of the films made.

Table 2- Result of the physical characterization of the analyzed fruits.

| Parameters | Central empress market | Senator Lá Roque and João Lisboa | Anaás State of Tocantins |
|--------------------|------------------------|----------------------------------|--------------------------|
| Fruit weight (g) | 49,6 | 48,6 | 48,7 |
| Length (cm) | 6,7 | 5,7 | 5,9 |
| Diameter (cm) | 6,8 | 5,3 | 4,6 |
| Circumference (cm) | 13,6 | 10,6 | 9,2 |

Arimetic mean of the analyzed fruits. Forty individuals from each region were used. **Source:** Author.

According to Marinho & Castro (2002) and Yuyama et al (2008), *the fruits of Mauritia flexuosa* have an average weight of 50.8g and consist of 21.2g of mesocarp. Oliveira et al. (2004) reported that heterogeneity among species of the *genus Mauritia* is related to genetic and environmental factors, such as soil type, climate and fruiting period that could be determinant in differences in size, weight and fruit constitution.

The purpose of analyzing the characteristics of the buriti fruit is related to the production of the amount of dry mass produced by fruit. Thus, it is known how many fruits are needed for bioplastic production with the specifications.

In the results found, it was observed that the fruits acquired in the central market of Imperatriz had higher yield. This result differed from the others due to the location of where they were acquired as soil, rainfall index, among others.

4.2 BIOPATHIC PREPARATION

Prepared bioplastics can be seen in figure 13). The pre-injunction tests showed that among the samples produced at s that demonstrated a plastic material with a higher viscoelastic consistency were samples 1, 2, 3, 7 and 8. The sample 11 obtained a lower and slightly rigid elasticity, while the bioplastic samples 14 and 15 were verified greater stiffness and without flexibility.

In samples 1, 2, 3, 4 and 5, it is visually similar to a synthetic plastic film, when compared to the other samples, which is perceived as a yellowish coloration, this is due to the fact that the materials were produced from the pulp of the buriti (mesocarp).



4.3 CHARACTERIZATION OF BIOPLASTICS IN DIFFERENT EVALUATIONS

4.3.1 Subjectivity assessment

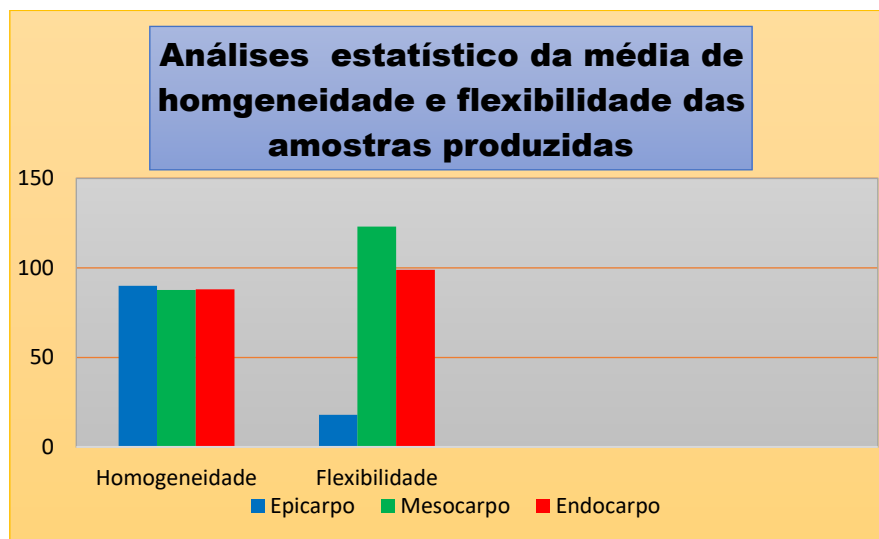
The evaluation of subjectivity aimed to verify the characteristics of homogeneity, flexibility, uniform staining, removal of glass plate, exemption of insoluble particle and bubble in the 15 samples. After this evaluation, a comparison was made of the mean between the epicarp bioplastics, mesocarp and endocarp table 03.

| Materials | Homogeneity | Flexibility | P. of bubbles | Deformation |
|-----------|-------------|-------------|---------------|-------------|
| Epicarp | 90.0 % | 18th | No | 11 failures |
| Mesocarp | 87,6 % | 123rd | 10 | 06 failures |
| Endocarp | 88.0 % | 99th | 03 | 09 failures |

Average results obtained among the 15 samples studied. Source: Authors

Analyzing the result, it was observed that the epicarp presented homogeneity that mesocarp and endocarp may present in may. This was due to the greater presence of additive (cassava starch) in the production of bioplastic samples. The characteristics of homogeneity and flexibility are the most important in the production of a bioplastic.

Graph 01 shows the statistical aspects of the results found, with the higher focus for homogeneity percentage and flexibility angle. These two parameters are extremely necessary to work the technological production of utensils derived from bioplastic.



4.3.2 Thickness of bioplastics

The thickness of bioplastics should be as homogeneous as possible to avoid mechanical and conservation problems. It must be established taking into account the final use of the film, which will depend of the food to be packed Sarmiento, (1999). According to Sobral (1999), when controlling the thickness, the formulation of the biofilm should be taken into account.

According to Gennadios et al. (1993), to maintain the uniformity of the films, as well as to ensure the repeatability of the measurements of their properties, as well as the comparison between biofilms, it is necessary to control the thickness.

The thickness can influence the permeability to water vapor of bioplastics, due to structural changes caused by swelling of the hydrophobic matrix, which affects the structure of the films and causes stresses that can influence permeation (PARK, CHINNAN, 1995).

Table 04 shows the values obtained from the thickness in four different points from the bioplastics produced from the epicarp, mesocarp and endocarp.

| Samples | 1st measure | 2nd measure | 3rd measure | 4th measure |
|-----------------|-------------|-------------|-------------|-------------|
| Epicarp | 0.080mm | 0.069mm | 0.062mm | 0.066mm |
| Mesocarp | 0.126mm | 0.11mm | 0.084mm | 0.102mm |
| Endocarp | 0.14mm | 0.148mm | 0.122mm | 0.15mm |

Average measurements of the 15 samples produced. Source: Authors

Nalisando the thickness picture, it is noted that the bioplastic of the epicarp presented an average of 0.06925mm, which multiplied by 100 obtained the average 6.93mm. The mesocarp had its average of 0.08075 mm, resulting in 8.1 mm. Endocarp reached the following average thickness 0.14mm, with a final result of 14mm.

The diagnosis of the results is observed that the endocarp presented greater thickness 14mm, with this development it can be said that the endocarp is ideal for producing biodegradable acrylic objects. The epicarp and mesocarp, respectively, presented smaller thicknesses, where the epicarp 6.93mm is ideal for producing material for wall cladding figure 20, while the 8.1mm mesocarp has the standard for manufacturing biodegradable bags.

According to Albuquerque & Malafaia, (2018). Bioplastic can be used as a packaging or coating applied to the surface of the food and must have some characteristics: barrier properties to oxygen, water and/or fats, as well as mechanical properties comparable to conventional plastics; microbiological, physical-chemical, thickness and biochemical stability; absence of toxic or harmful components to health, among others.

4.3.3 Tests chemical resistance of materials produced

The material was divided into small fragments and then placed in specialized liquids, the same used in daily life at home (soap, detergent, alcohol and acetone). The objective of this test was to verify the resistance in the domestic use of the utensils produced and to verify that it is resistant for a period of time. Thus, it is possible to predict the validity of the same.

Table 05 shows what occurred after 48 hours that the material was submerged

| Materials | Soap water | Detergent | Acetone | Ethyl alcohol |
|---------------------|------------|-----------|-------------|---------------|
| Epicarp bioplastic | Normal | Normal | P. coloring | +Flexibility |
| Mesocarp bioplá | Normal | Normal | P. Coloring | +Flexibility |
| Endocarp bioplastic | Normal | Normal | P. coloring | +Flexibility |

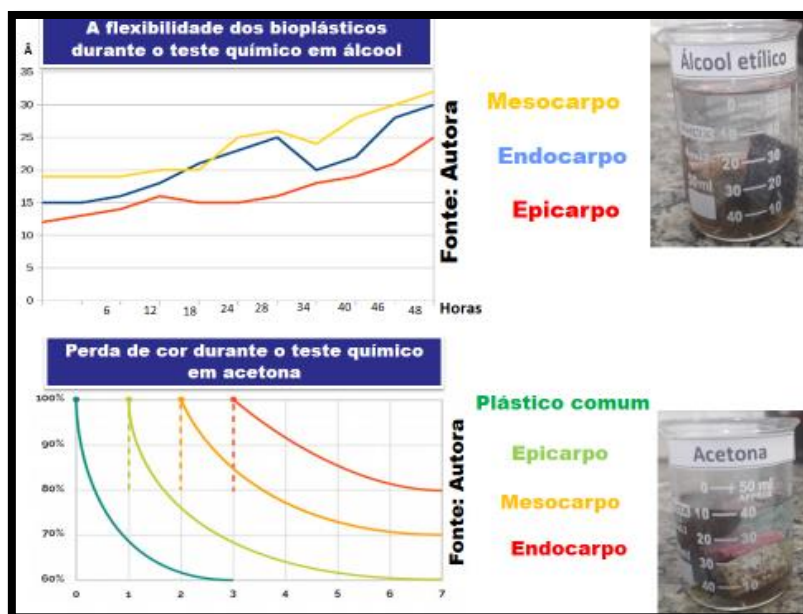
P - loss. + Greater flexibility. Source: Author - 2021

Observing tabelat 05, it is noted that there was a change only in the assays that used acetone and alcohol and ethyl, this fact occurred due to acetone having in its composition chemical element that is solvent

and ethyl alcohol penetrate more easily in the granules of bioplastics. Even with these two occurrences, there was no deformation in the fragments used in the tests.

According to Zobel (1998), domestic chemical reagents are prevented from penetrating between molecules, and when they penetrate they do not destroy the organization of biopolymers, because the granules have some zones of crystalline rigid structure and other amorphous ones.

Graph 02 shows that fragments of bioplastics dipped in alcohol have changed their flexibility. The strapils produced with the buriti mesocarp (fruit pulp) had flexibility of 18 degrees before the test, after 48 hours changed their flexibility to 32 degrees, a variation of 14 degrees. The endocarp had a variation of 15 degrees ($15^{\circ} - 30^{\circ}$). Already epicarp had the smallest remodeling in its flexibility, 8 degrees. At the beginning of the test it had 12 degrees of malleability after 48 hours 20 degrees. This smaller variation occurred because the material used was more compact.



According to Sousa, (2021), alcohol is used as a vehicle in cosmetic formulations and as a general cleaner for health care. Due to its high concentration of 96% does not cause the denaturation of the microorganism proteins or its destruction, and then does not have the action of disinfection. Alcohol destroys the outer cell membrane by dehydration, after all alcohol is hygroscopic and hydrophilic. Alcohol molecules penetrate the cytoplasm and, as a result, precipitate proteins due to denaturation.

It can be seen that the malleability that occurred in the fragments used in the experiments was caused by the penetration of alcohol into the molecules of bioplastic shards. After an hour the material returned to its original flexibility, this happened because the alcohol was volatile.

Graph 03 is the result of the assays using bioplastic fragments produced from the epicarp, mesocarp and endocarp of the buriti fruit, dipped in acetone. For comparison used a piece of ordinary plastic.

Analyzing the results, it is observed that all materials have lost their coloration, this occurs, because acetone is a solvent.

According to Fogaça (2021), acetone is a colorless liquid, soluble in water (due to the fact that it is polar, as well as water) and in organic solvents, it smells pleasant and flammable. Its main characteristic is to act as solvent, being therefore used as solvent of paints, enamels, varnishes, in the extraction of vegetable seed oils, in the manufacture of medicines, acetic anhydride, in the preparation of chloroform, iodoform

Thus, the color loss was more pronounced in the bioplastic fragments of the endocarp (80%). The endocarp shards were colored with plant extracts without industrial fixator, thus facilitating the discoloration. The lowest color loss occurred with traditional plastic (60%) and epicarp bioplastic (60%). It is important to inform that traditional plastic is industrially made and has the presence of fixer. The bioplastic of the epicarp (bark) was produced by hand using its natural color without fixator.

4.3.4 Mechanical properties of bioplastics produced

For the result of mechanical properties, 15 samples were analyzed, 05 of each part of the fruit (epicarp, mesocarp and endocarp). The strength and characteristics of bioplastics to compression (fck) were analyzed, where its unit of measurement is Mpa (Mega Pascal).

With what can be observed in Table 05, the elevation of the concentration of the matrix and additive (cassava starch) of the epicarp, from 2.9 to 3.6g, of the mesocarp from 2.0 to 2.4g and of the endocarp from 2.0 to 2.6g caused an increase in the thickness of all biofilms studied. This property also increased with the increase in the amount of glycerol and acetic acid, which may have influenced the elongation value and resistances for the epicarp, mesocarp and endocarp films in the proportion of the matrix with the additive (PVA - polymer).

According to Fakhouri (2003), he found that increasing protein concentration in simple films of gelatin plasticized with triacetin causes an increase in thickness and PVA.

Table 06. Mechanical properties and flexibility of the bioplastics of the buriti fruit (epicarp, mesocarp and endocarp) and cassava starch, plasticized with glycerol and acetic acid.

| Samples | Proportion/g | Stretching % | Attraction resistance /MPa |
|--------------|--------------|--------------|----------------------------|
| 001 epicarp | 2.9 M+A | 2,54 | 80,32 |
| 002 epicarp | 2.9 M+A | 5,80 | 82,51 |
| 003 epicarp | 3.6 M+A | 0,86 | 86,54 |
| 004 epicarp | 3.6 M+A | 1,68 | 98,81 |
| 005 epicarp | 3.5 M+A | 2,50 | 97,83 |
| 006 mesocarp | 2.0 M+A | 4,34 | 39,41 |
| 007 mesocarp | 2.1 M+A | 2,58 | 39,44 |
| 008 mesocarp | 2.2 M+A | 1,72 | 39,82 |
| 009 mesocarp | 2.3 M+A | 1,70 | 43,52 |
| 010 mesocarp | 2.4 M+A | 2,63 | 46,21 |
| 011 endocarp | 2.0 M+A | 5,21 | 43,16 |
| 012 endocarp | 2.2 M+A | 5,04 | 39,72 |
| 013 endocarp | 2.3 M+A | 3,47 | 39,81 |
| 014 endocarp | 2.6 M+A | 4,16 | 44,15 |
| 015 endocarp | 2.6 M+A | 4,20 | 45,69 |

M +A - Matrix and additive (epicarp powder, mesocarp, endocarp and cassava starch).

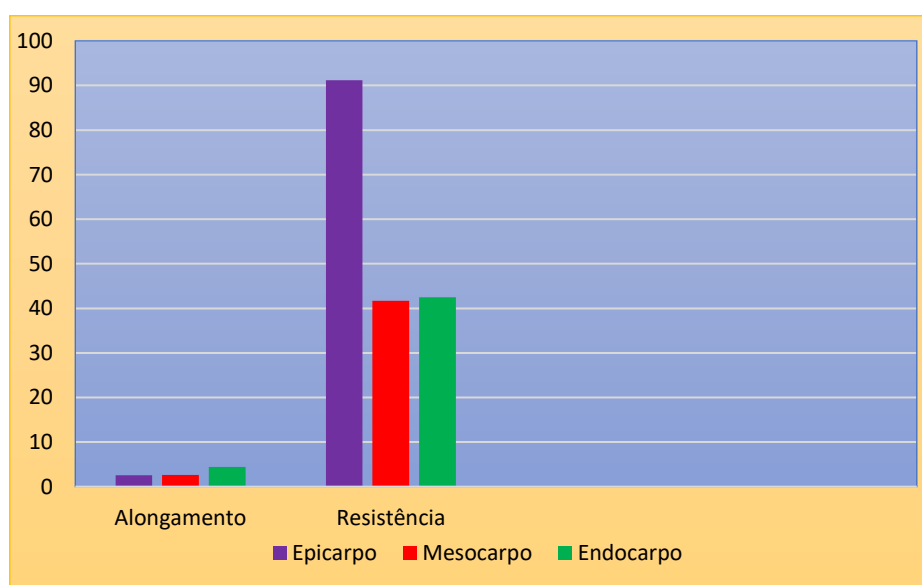
MPa - Mega Pascal.

Results analysed in the physics laboratory of UEMASUI - 2021.

Analyzing the table, it is observed that the proportion in gram of the matrix with the additive increases the resistance (3.6g - 86.54Mpa, 3.6g - 98.81Mpa and 3.5g - 97.83Mpa) **and decreases** elongation, that is, the material becomes more compact and less flexible.

Therefore, the bioplastic produced with the epicarp (fruit peel powder) was more resistant. It is possible to use it in wall coverings, floor coverings, furniture and in the design of household items. The most flexible can be used in the production of bags and glasses.

Graph 03 presents a comparison between elongation and endurance. It can be noted that epicarp presented low elongation (2.67%) and high resistance (91.20 Mpa), while endocarp presented higher elongation (4.41%) and low resistance compared to the epicarp (42.50Mpa). The results presented in the graph are the means of the analyzed values of epicarp bioplastics (05), mesocarp (05) and endocarp (05).



Source: Author - 2021

Graph 03 is in accordance with the study by Eduardo (2019), which analyzed different films in different concentrations of starches and additives, which more concentrated matrix solutions produced films more resistant to drilling and traction.

4.3.5 Color and opacity of bioplastics

One of the burdens of bioplastics is to make the consumer see the different characteristics of color and transparency, that a more attractive genre is presented, as with the other common plastics found in the market. The characterization of the visual aspect and opacity constitutes an important procedure because these properties directly influence the production of utensil that will be offered to the general public. The transparency of bioplastics and flexibility makes the material an attractive product.

Table 07 shows the result obtained from the mean luminosity radius and opacity of bioplastics produced with epicarp, mesocarp and endocarp of buriti fruit.

| Bioplastics | Op. From black background | Op. White background | Med. Result | Op. real |
|--------------------|----------------------------------|-----------------------------|--------------------|-----------------|
| Epicarp | 0.6 cm | 0.66 cm | 0.63 cm | 0.0063mm |
| Mesocarp | 3.04 cm | 1.86 cm | 2.45 cm | 1.66 mm |
| Endocarp | 1.48 cm | 1.96 cm | 1.72 cm | 0.017mm |

*Op. opacity. *Med. Medium. **Source:** Author

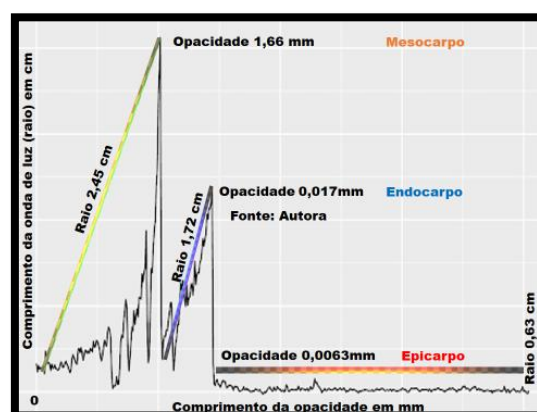
Analyzing table 06, it was observed that the mesocarp presented the length of light 2.45cm (mean) radius and opacity 1.63mm. In this case, the bioplastics of the mesocarp are considered as transparent bodies by the sharpness through these, where the light rays find it easy to cross without interfering with their vision. Therefore, this material can be used in the manufacture of bags, biofilms and curtains for bathrooms.

The endocarp presented a luminous radius length of 1.72cm (mean) and opacity of 0.017mm. Therefore, the material is considered as translucent bodies not allowing going to total visualization through this. With this configuration, translucent bioplastic can be used in the manufacture of biodegradable acrylic materials.

The epicarp presented the length of the radius 0.63 cm (mean) and opacity of 0.0063mm. With this result, bioplastics produced with epicarp of buriti fruit (bark), are considered as opaque bodies do not allow the passage of light rays, being effective in wall cladding and flooring.

According to Chen (1995), the color and opacity of the polymer is a consequence of morphology or chemical structure related to the molecular mass of the material. Gelatin-based films are transparent and homogeneous (FAKHOURI et al. 2003), while the addition of lipids changes the appearance of hydrocolloid films leaving them opaque (KAMPER, FENNEMA, 1984). This fact was also observed by Fakhouri et al. (2003) in gelatin biofilms added of uric acid, palmitic and stearic acid and also by Yang, Paulson (2000) in gelana gum biofilms added of palmitic and stearic acid.

In graph 05 it is possible to notice the opacity scaling, where it is determined according to the chemical structure of each material, that is, the amount of the addition of the matrix and additive. The larger the amount of the matrix the greater the transparent, when added additive changes appearance getting more opaque.



Source: Author

Graph 5 shows that the mixtures containing a concentration of 70% matrix and 30% additive formed a more opaque bioplastic, i.e., low wavelength. Thus occurred with the materials produced with the bark of the buriti fruit (epicarp). The increase in matrix content by 98% and the decrease in the value of the additive to 2% promoted bioplastics with greater transparency (mesocarp). Bioplastics developed with 90% matrix and additive 10% presented median opacity values, considered as translucent.

4.3.6 Water solubility

The solubility in water increased with the increase of the amount of matrix in the biopásticos at the concentration of 98% (Table 8). On the other hand, for epicarp and mesocarp bioplastics, it does not differ significantly from the proportion of the mass difference 3.95g and 3.09g, but also an increase in permeability was observed with increased concentration of additive (cassava starch) and glycerol plasticization.

Table 08 behavior of bioplastics produced with epicarp, mesocarp and endocarp of buriti fruit, after the water solubility test.

| Samples | Dry weight | Wet weight | Mass difference | Weight of final mass |
|----------|------------|------------|-----------------|----------------------|
| Epicarp | 23.68g | 27.60g | 3,92 | 0.165g |
| Mesocarp | 6.48g | 9.57g | 3.09g | 0.416g |
| Endocarp | 4.90g | 8.90g | 4.0g | 0.816g |

Result based on the average of the 15 samples produced. Source: Authors

The endocarp showed a greater mass difference, because it is a more porly bioplastic, facilitating water penetration. The epicarp and mesocarp had similar results, this fact occurred, because the molecules of the bark (epicarp) and pulp (mesocarp) are more concentrated.

However, the bioplastics composed of the buriti fruit with the cassava starch additive plasticized with glycerol were 100% soluble in acid.

4.3.7 Temperature resistance

The 15 bioplastic samples produced from the buriti fruit were placed in Petri dishes, and 120°C) for 20 minutes to verify at what temperature the bioplastics were deformationd. In this case, deformations, cracks, dryness, curves that suggest in the treatments were considered.

Table 09 shows the means of the temperature resistance tests of the bioplastics tested.

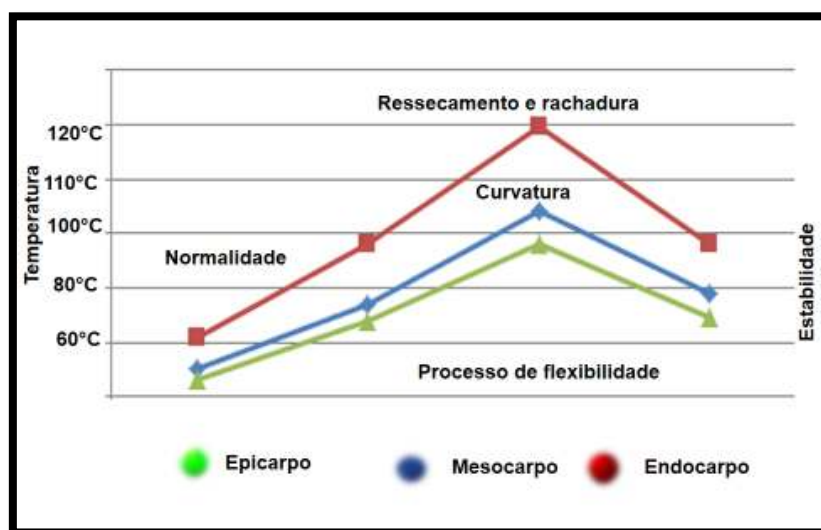
| Samples | It has 60°C | It has 80°C | It has 100°C | It has 110°C | It has 120°C |
|----------|-------------|-------------|--------------|--------------|--------------|
| Epicarp | Normal | Normal | Normal | Normal | Crack |
| Mesocarp | Normal | Normal | Curve | Curve | Crack |
| Endocarp | Normal | Normal | Curve | Curve | Dryness |

Source: authors

All treatments submitted to the temperature resistance test were observed normality at temperatures 60 and 80°C of bioplastic samples, but at temperatures of 100 and 110°C, the epicarp presented normality, while the mesocarp and endocarp showed curvature. At the temperature of 120°C epicarp and mesocarp presented cracks and dry endocarp.

After the temperature resistance test, the epicarp and mesocarp samples remained in 95% of their texture within normal range, while endocarp only 90%. This result is taken into account at temperatures of 100, 110 and 100°C.

Graph 06 contextualizes the behavior of the samples in temperature tests.



Source : Author

Analyzing a graph, it is observed that all samples undergone significant modification from 100 degrees. When it reaches 120 degrees increases flexibility, starts drying and cracks, at this moment the polymers molecules distance one from each other causing deformation in the samples. The temperature assays went beyond the tests with temperatures used by other experiments that were 80 degrees.

4.3.8 Evaluation of biodegradation in water and in the case of bioplastic samples

Costa (2012) indicates that biodegradation is a process that occurs through the action of microorganisms present in the environment, to which specific enzymes break the polymer chain digesting it. In the water were found aspergillus and yeasts, already in the soil were found bacteria deceding pseudomonas and aspergillus.

It was also verified that the degradation was more pronounced in the material placed in the water in a period of exposure in the laboratory (15 days), because there was degradation of approximately 85% in 10 days and 100% in 15 days for all samples. In the tests using soil, decomposition occurred in 20 days (100%). In 15 days 90% of the material was already decomposed.

A similar situation occurred in a study conducted by Dalmolin (2007), with plastic bags of PE, exposed to the weather for a period of one year. In just 70 days of exposure, the molar mass of polyethylene decreases by around 40%, reaching 95% in 140 days of exposure to weathering.

4.3.9 Tests using degradation residues in a garden plant

For thirty days, residues of the decomposition of bioplastics produced in the research project in a garden plant of the greenhouse of UEMASUL were used. Daily was monitored to verify the behavior of the species used. After the first five days the species remained their normal color and growth in 1cm.

The by-product of degradation proved to be an adequate residue for plant fertilization without causing harm to the environment. These residues presented a physicochemical composition with possible potential for fertilization application in small gardens, mainly because of its high nutrient content.

FIVE, FIVE OF THEM. BIOPLASTIC PRODUCTION IN DIFFERENT SIZES

After all tests, different bioplastics were produced to be used with decorative material. These materials were submitted to all tests (flexibility, temperature resistance, chemical resistance, durability, opacity, color and degradation).

With these results it is possible to affirm that the bioplastics produced from the epicarp, mesocarp and endocarp of the buriti fruit is a material with biotechnological scientific potential, generating a delta of opportunity to solve the problems caused by ordinary plastic.

5 CONCLUSION

The production of composite bioplastics based on the epicarp, mesocarp and endocarp of the fruit of the buriti additive with cassava starch, plasticized with glycerol, is feasible by the following factors:

- It uses technology for sustainable development and technology for social unfolding;
- It has innovation in the application of buriti fruit, for the production of bioplastics and biofilm that can be used in the polymer industry and in the pharmaceutical industry, without harming the environment because it is biodegradable in water and soil;
- The epicarp and endocarp can be used in the production of biocomposite and biodegradable acrylic material;
- The materials produced that had the lowest amount of additive increased their resistance to temperature, thus facilitating the socioeconomic unfolding.

In general, it was observed that the values applied in the tests with bioplastics, even in a simple way presented positive outcome. All bioplastics studied, tiveram results unwrapped in the process of biodegradation in water and soil.

In the interface of this research, meta-requirements for Eco-feedback solutions in bioplastic of socioeconomic and socio-environmental interest were identified. Expanding the validity of the

requirements obtained through the intense involvement of production and in the definition of the eco-feedback profile most appropriate to environmental issues for the present and future.

Within the scientific aspect , the research scanted a plastic of the buriti fruit (bioplastic) to improve its its suitability to the polymer matrix, testing the epicarp, mesocarp and endocarp with cassava starch additive in different measurements in polymeric processing, using the cooking and cooling process. Thus, the project is framed within the Enabling Technologies Area covering the following sectors: Environmental Biotechnology and Environmental Sciences.

REFERENCES

- ALBUQUERQUE, P. B. S., & Malafaia, C. B. (2018). Perspectives on the production, structural characteristics and potential applications of bioplastics derived from polyhydroxyalkanoates. **International Journal of Biological Macromolecules**, 107(Pt A), 615-625. PMID: 28916381. <http://dx.doi.org/10.1016/j.ijbiomac.2017.09.026>
- ARAÚJO, J. R.; WALDMAN, W. R. & De PAOLI, M. A. - **Polym. Degrad. Stab.** **93**, p.1770 (2008). <http://dx.doi.org/10.1016/j.polymdegradstab.2008.07.021>
- BALZER, P; FELTRAN M.B.; RODOLFOJUNIOR; SOLDI,V; BECKER, D; BRIESEMEISTER. R.;VICENTE,L. Estudo das Propriedades Mecânicas de um Composto de PVC Modificado com Fibras de Bananeira Polímeros: **Ciência e Tecnologia**, vol.17, n1, p.1-4, 2007
- BARBOSA, L.; CAMPBELL, C. **Cultura, consumismo e identidade**. 2. ed. Rio de Janeiro: FGV, 2015.
- BARROS, T. D. ; JARDINE J. G. **Árvore do Conhecimento**. Ageitec Agência Embrapa e Informação Tecnológica – EMPBRAPA – Pará, 2020.
- BRASIL, ABNT (Associação Brasileira de Normas Técnicas) Embalagens Plásticas Degradável. NBR – 1544-2. 01/2018.
- CARASHI, J. C. & LEÃO, A. L. **Polímeros**. Congresso Brasileiro de Polímeros, in: Anais do 6º Congresso Brasileiro de Polímeros, Gramado-RS, p.566, 2001.
- CHEN, H. Functional properties and applications of edible films made of milk proteins. **Journal of Dairy Science**, 78: 2563-2583, 1995.
- DALMOLIN, E. **Avaliação da degradação de polietilenos contendo aditivo pró-degradante**. [Dissertação]. Porto Alegre: Universidade Federal do Rio Grande do Sul; 2007. 74
- EDUARDO, L. F., Análise de biofilmes produzidos com amido de batata e gelatina incolor. Artigo de conclusão de **Espacialização em Ciências Ambientais** da Universidade Estadual do Maranhão. São Luis, 2019.
- FECHINE, G. J. M. *et. al.*. Estudo da biodegradabilidade de polímeros por meio do respirômetro de bartha. **Rev. Mackenzie de Engenharia e Computação**, v. 11, n. 1 – Ed. Especial, p. 46-55, 2011
- FERNANDES, V.; MARTENDAL, C. **Bioplásticos**. Disponível em: <<http://engenheirodemateriais.com.br>> Acesso em 04/05/2021.
- FRANCHETTI, S. M. M.; MARCONATO, J. C. Polímeros biodegradáveis: uma solução parcial para diminuir a quantidade dos resíduos plásticos. **Química Nova**, v. 29, n. 4, p.811-816,2006.
- FONSECA, J. J. S. **Metodologia da pesquisa científica**. Fortaleza: UEC, 2002. Apostila.
- FOGAÇA, J. R. V. Propano ou acetona **Revista eletrônica Mundo Educação**. Acessada em 07 de maio de 2021. <https://mundoeducacao.uol.com.br/quimica/propanona-ou-acetona.htm>
- FAKHOURI . F. M. **Tese de Mestrado**, Universidade Estadual de Campinas, 2003.

FAKHOURI F. M. ; BATISTA J. A. ; GROSSO C.R.F. Desenvolvimento e Caracterização de Filmes Comestíveis de Gelatina, Triacetina e Ácidos Graxos, **Brazilian Journal of Food Technology**, vol6, n2, 301-308, jul/dez 2003.

GENNADIOS, A., WELLER, C. L.; TESTIN, R. F. Property modification of edible wheat, gluten-based films. **Transactions of the American Society of Agriculture Engineers**, 36: 465-470, 1993

GUIMARÃES JR, M.; BOTARO, V. R.; NOVACK, K. M.; TEIXEIRA, F. G.; TONOLI, G. H. D. Starch/PVA-based nanocomposites reinforced with bamboo nanofibrils. **Industrial Crops and Products**, v. 70, p. 72-83, 2015.

GREEN, Paul & TULL, Donald S. **Research for marketing decisions**. 2. ed., New Jersey. Prentice-Hall. p, 467. Edição 2018

KAMPER, S. L., FENNEMA, O. Water vapor permeability of an edible, fatty acid bilayer film. **Journal of Food Science**, 49: 1482-1485, 1984b

INNOVA. **História do plástico**. Disponível em: <<http://innova.ind.br/>>. Acesso em: 22 junho 2021.

INSTITUTO SOCIOAMBIENTAL (ISA). Almanaque Brasil Socioambiental: **LIXO**. São Gabriel da Cachoeira: Editora do Instituto Socioambiental, 2005. pp. 398. 2005.

JIMÉNEZ, A.; FABRA, M. F.; TALENS, P.; CHIRALT, A. Edible and biodegradable starch films: a review. **Food and Bioprocess Technology**, v. 5, p. 2058-2076, 2012.

LEITE, P. J. F. *et. al.*. Poliestireno biodegradável para embalagens descartáveis: Desenvolvimento da Blenda pela incorporação de amido de mandioca. **TECBAHIA Rev. Baiana de Tecnologia**, vol. 14, nº 1, pp126-130, 1999.

MACHADO, B. A. S.; REIS, J. H. O.; SILVA, J. B.; CRUZ, L. S.; NUNES, I. L.; PEREIRA, F. V.; DRUZIAN, J. I. Obtenção de nanocelulose da fibra de coco verde e incorporação em filmes biodegradáveis de amido plastificado com glicerol. **Química Nova**, v. 37, n. 8, p. 1275-1282, 2014

MORAES, J. O. **Propriedades de filmes de amido incorporados de nanoargilas e fibras de celulose**. Florianópolis, 75 p. Dissertação (Mestrado em Engenharia de Alimentos) - Universidade Federal de Santa Catarina, Santa Catarina, 2009.

MOLINA, F. M. P. **Produção e caracterização de filmes biodegradáveis de amido e farinha de banana reforçados com nanofibras de celulose**. Campinas, 209 p. Tese (Doutorado em Engenharia de Alimentos) - Universidade Estadual de Campinas, São Paulo, 2013.

OLIVEIRA, A.; RODRIGUES, A.; DIAS, R.; LORENTZ L.; LAVORATO M.; TAGLIANI S. **Conheça tudo sobre o bioplástico**. Disponível em: <<http://www.pensamentoverde.com.br>> Acesso em: 04/04/2017, 2021.

OLIVEIRA, A.; RODRIGUES, A.; DIAS, R.; LORENTZ L.; LAVORATO M.; TAGLIANI S. **Conheça tudo sobre o bioplástico**, 2014.

PARK, H. J., CHINNAN, M. S. Gas and water vapor barrier properties of edible films from protein and cellulosic materials. **Journal of Food Engineering**, 25, 497- 507, 1995.

PIATTI, T. M.; RODRIGUES, R. A. F. **Plásticos: características, usos, produção e impactos ambientais**. Série: Conversando sobre Ciências em Alagoas. Maceió. 51 p. 2005.

PIMENTEL, T. A. P. F.; DURÃES, J. A.; DRUMMOND, A. L.; SCHLEMMER, D.; FALCÃO, R. & SALES, M. J. A. - **J. Mater. Sci.**, **42**, p.7530 (2007).

QUEIROZ, T. 2010. **Consumo, Consumismo e os impactos no Meio Ambiente**. Disponível em: <<http://www.recicloteca.org.br>> Acesso em 22 abril 2021.

RAMIRES, E. C.; MEGIATTO JÚNIOR, J. D.; GARDRAT, C.; CASTELLAN, A. & FROLLINI, E. - **Bioresour. Technol.**, **101**, p.1998 (2010).

RODRIGUES, K.; LIMA, M. GONZALES, M.; KRETZMANN, N. **Produção de bioplástico a partir da casca da batata (*Solanum tuberosum*)**. Anais XI Semana de Extensão, Pesquisa e Pós- Graduação do Centro Universitário Ritter dos Reis, p. 8, 2015.

RUDIN, A.; CHOI, P. **Ciência e engenharia de polímeros**. 1. ed. Rio de Janeiro: Elsevier Brasil, 2016.

SANTOS, B.; SILVA, R. S; COELHO, T. M.; ASSAD FILHO, N. **Produção de Bioplástico a partir do amido de mandioca**. Anais do VIII Encontro Internacional de Produção Científica. Maringá, 5 p, 2013.

SAMPAIO, M. B. **Boas práticas de manejo para o extrativismo sustentável do buriti**. Brasília, DF: [s.n], 2011. 80 p

SAMPAIO; CARRAZZA **Boas práticas de manejo para o extrativismo sustentável do fruto buriti**. Brasília, DF. 2012.

SANTOS, C. D. M.; PAGNO, C. H.; COSTA, T. M. H.; FACCIN, D. J. L.; FLÔRES, S. H.; CARDOZO, N. S. M. Biobased polymer films from avocado oil extraction residue: Production and characterization. **Journal of Applied Polymer Science**, v. 133, p. 43957 (1-9), 2016.

SANTANA, J. S.; ROSÁRIO, J. M.; POLA, C. C.; OTONI, C. G.; SOARES, N. F. F.; CAMILLOTO, G. P.; CRUZ, R. S. Cassava starch-based nanocomposites reinforced with cellulose nanofibers extracted from sisal. **Journal of Applied Polymer Science**, v. 134, p. 44637 (1-9), 2017.

SARMENTO, A. L. S. C. **Elaboração e Caracterização de Biofilmes a partir de Gelatina Reticulada**. Tese de Mestrado FEA- UNICAMP,1999.

SILVA, J. B. A; NASCIMENTO, T.; COSTA, L. A. S.; PEREIRA, F. V.; MACHADO, B. A.; GOMES, G. V. P.; ASSIS, D. J.; DRUZIAN, J. I. Effect of source and interaction with nanocellulose cassava starch, glycerol and the properties of films bionanocomposites. **Materials Today: Proceedings**, v. 2, p. 200-207, 2015.

SOBRAL, P. L. J. Propriedades funcionais de gelatina em função da espessura. **Ciência e Engenharia (Science and Engineering Journal)**, 8: 60-67, 1999

SOUZA, A. C. **Desenvolvimento de embalagem biodegradável ativa a base de fécula de mandioca e agentes antimicrobianos naturais**. São Paulo, 136 p. Tese (Doutorado em Engenharia Química) - Escola Politécnica da Universidade de São Paulo, São Paulo, 2011.

SOARES, E. F. Aproveitamento Sustentável da *Mauritia flexuosa*. Anais da Mostratec 2010.

SOARES, Z. T. Buriti Palmeira da Vida, Universidade Estadual da Região Tocantina do Maranhão, *Anais 2020 SAPIENS*, Imperatriz Maranhão.

TOMCZAK, F.; SATYANARAYANA, K. G. & SYDENSTRICKER, T. H. D. - **Composites: Part A**, **38**, p.2227 (2007). <http://dx.doi.org/10.1016/j.compositesa.2007.06.005>

UFCG, 2017. **Alexander Parkes**. Disponível em: <<http://www.dec.ufcg.edu.br/biografias>> Acesso em: 06 de junho de 2021.

ZANIN, M., MANCINI, SD. Resíduos plásticos e reciclagem: aspectos gerais e tecnologia. 2nd ed. São Carlos: EdUFSCar, 138 p., 2015.

YANG, L.; PAULSON, A. T. Effects of lipids on mechanical and moisture barrier properties of edible gellan film. **Food Research International**, 33: 571-578 2000. ZANIN, M., MANCINI, SD. **Resíduos plásticos e reciclagem: aspectos gerais e tecnologia**. 2nd ed. São Carlos: EdUFSCar, 138 p., 2015.