RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

OBTAINING BIODEGRADABILITY FILM OF CASHEW (ANACARDIUM OCCIDENTALE) RESIDUE FROM THE CARIRI REGION FOR FOOD

OBTENÇÃO DE FILME DE BIODEGRADABILIDADE DE RESÍDUO DE CAJU (ANACARDIUM OCCIDENTALE) DA REGIÃO DO CARIRI PARA ALIMENTAÇÃO

OBTENCIÓN DE UNA PELÍCULA DE BIODEGRADABILIDAD DEL RESIDUO DE ANACARDO (ANACARDIUM OCCIDENTALE) DE LA REGIÓN DEL CARIRÍ PARA LA ALIMENTACIÓN HUMANA

Isis Alves Palmeira[1], Raimundo Ruan Ferreira Rodrigues[2], Carmen Luce Duarte da Silva[3], Adriana Machado[4], Antônio Matias Navarrete Toledo[5], Maria Inês Rodrigues Machado[6]

e595666
https://doi.org/10.47820/recima21.v5i9.5666

RECEIVED: 08/03/2024 APPROVED: 09//03/2024 PUBLISHED: 09/18/2024

ABSTRACT
Brazil is one of the leading food producers, but it still faces the reality of food waste. The use of fruit residues in the production of new products is a clean and sustainable technological alternative. The objective of this work was to characterize biodegradable films produced from natural raw materials and dehydrated organic cashew residues, in terms of thickness, weight, density, permeability, solubility, transparency, and moisture. The results obtained in the analyses were: Thickness: 0.046 cm; Weight: 0.039 g/cm²; Density: 0.85 g/cm³, Permeability: 372.4 g/(dia.cm²), Solubility: 29.33%, Transparency, measured in Transmittance 0.48 nm and Humidity: 9%. From the data obtained, we can infer that the films produced are of low thickness and weight which allows its high flexibility, ideal for food coating, the density found is lower than the density of water, which is an important parameter for its biodegradation, the permeability found was also low. Being an important characteristic because it is the one that allows the interaction with the external environment when the product is stored and, thus, configures the protection to the product, the solubility analysis revealed a low value similar to those found in the literature, which is ideal for the packaging of food products rich in water activity, Thus, a film with low humidity provides even more preservation to food. The films obtained presented favorable characteristics for food preservation.

KEYWORDS: Analysis. Feeding. Conservation. Protection. Renewable.

RESUMO
O Brasil é um dos principais produtores de alimentos, mas ainda enfrenta a realidade do desperdício de alimentos. A utilização de resíduos de frutas na produção de novos produtos é uma alternativa tecnológica limpa e sustentável. O objetivo deste trabalho foi caracterizar filmes biodegradáveis produzidos a partir de matérias-primas naturais e resíduos orgânicos desidratados de caju, quanto à espessura, peso, densidade, permeabilidade, solubilidade, transparência e umidade. Os resultados obtidos nas análises foram: Espessura: 0,046 cm; Peso: 0,039 g/cm²; Densidade: 0,85 g/cm³, Permeabilidade: 372,4 g/(dia.cm²), Solubilidade: 29,33%, Transparência, medida em Transmitância 0,48 nm e Umidade: 9%. A partir dos dados obtidos, podemos inferir que os filmes produzidos são de baixa espessura e peso o que permite sua alta flexibilidade, ideal para revestimento de alimentos, a densidade encontrada é menor que a densidade da água, que é um parâmetro importante para sua biodegradação, a permeabilidade encontrada também foi baixa. Sendo uma caraterística importante, pois é ela que permite a interação com o meio externo quando o produto está armazenado e, assim, configura a proteção ao produto, a análise de solubilidade revelou um valor baixo e semelhante aos

[1] Estudante de Graduação em Agronomia, Universidade Federal do Cariri(UFCA).
[2] Estudante de Graduação em Agronomia, Universidade Federal do Cariri(UFCA).
[3] Tecnólogo em Alimentos, Universidade Federal de Pelotas (UFPEL).
[4] Doutora em Engenharia e Ciência de Alimentos, Universidade Federal do Rio Grande (FURG).
[5] Docente em Química no Instituto Federal de Educação, Ciência e Tecnologia, Suzano, SP.
[6] Docente do CCAB- Curso de Agronomia e Cursos de Medicina Veterinária na Universidade Federal do Cariri(UFCA).

encontrados na literatura, o que é ideal para o acondicionamento de produtos alimentícios ricos em atividade de água, assim, um filme com baixa umidade proporciona ainda mais preservação aos alimentos. Os filmes obtidos apresentaram características favoráveis para a conservação de alimentos.

PALAVRAS-CHAVE: Análise. Alimentação. Conservação. proteção. Renovável.

RESUMEN
Brasil es uno de los principales productores de alimentos, pero aún se enfrenta a la realidad del desperdicio alimentario. El uso de residuos de frutas en la producción de nuevos productos es una alternativa tecnológica limpia y sostenible. El objetivo de este trabajo fue caracterizar películas biodegradables producidas a partir de materias primas naturales y residuos orgánicos deshidratados de anacardo, en términos de espesor, peso, densidad, permeabilidad, solubilidad, transparencia y humedad. Los resultados obtenidos en los análisis fueron Espesor: 0,046 cm; Peso: 0,039 g/cm²; Densidad: 0,85 g/cm³, Permeabilidad: 372,4 g/(dia.cm²), Solubilidad: 29,33%, Transparencia, medida en Transmitancia 0,48 nm y Humedad: 9%. De los datos obtenidos podemos inferir que las películas producidas son de bajo espesor y peso lo que permite su alta flexibilidad, ideal para el recubrimiento de alimentos, la densidad encontrada es menor que la densidad del agua, que es un parámetro importante para su biodegradación, la permeabilidad encontrada también fue baja. Siendo una característica importante porque es la que permite la interacción con el ambiente externo cuando el producto es almacenado y, así, configura la protección al producto, el análisis de solubilidad reveló un valor bajo y semejante a los encontrados en la literatura, lo que es ideal para el envase de productos alimenticios ricos en actividad hídrica, Así, una película con baja humedad proporciona aún más conservación a los alimentos. Las películas obtenidas presentaron características favorables para la conservación de alimentos.

PALABRAS CLAVE: Análisis. Alimentación. Conservación. Protección. Renovable.

INTRODUCTION

According to the Food and Agriculture Organization of the United Nations (FAO), Brazil wastes about 64% of all annual food production. The use of food agribusiness by-products in a sustainable way reduces the production of organic waste and benefits family income, reduces production costs and the impact that these by-products can cause when discarded in the environment. In view of the food waste in the country, it is necessary to adopt measures for the use of waste, making the areas viable. Studies show that the use of films produced exclusively from starch is limited, reason evidenced by the low mechanical strength and high hydrophobicity evidenced in places with high relative humidity, generating fragile and hygroscopic films, however, the use of natural fibers of vegetable origin can alter this condition, such as fibers from the residues of the agroindustrialization of cashew, very abundant in the northeast of Brazil, providing reinforcement to starch polymer matrices, providing better mechanical properties and greater resistance to moisture, in addition to reducing costs and increasing biodegradability (Debiagi *et al*., 2012; Souza *et al*., 2012).

The cashew tree (Anacardium occidentale) is a tropical flowering tree that globally produces more than 4 million metric tons of cashew nuts per year (Cheng *et al*., 2023). According to Broinizi *et al*., (2007), the northeast of Brazil has a culture of great economic and social notoriety, cashew (Western Anacardium L.) The industry makes use of the stem in the preparation of juices, sweets and are directed mainly to the domestic market, throughout this process generates waste popularly called cashew bagasse and usually make the reuse of this material for the improvement of animal feed or despised for lack of knowledge in the use of human food (Pinho, 2009; Pinho *et al*., 2011). One of the many other problems that have been worrying the current society is what is done with this huge amount of waste that agglomerates and causes pollution and deterioration, as well as the dissipation of the natural resources present in the locality (Carioca; Arora, 2000; Pinho, 2009).

All these developments have resurrected the issue of the circular economic model. But the main reason why its effective application is discussed lies in the fact of the limitation of inputs resulting from the finiteness of natural resources (Azevedo, 2015).

To support the development of the field in terms of more satisfactory and sustainable production, circular economy practices are inserted in this context. In contrast to the largely linear "take-make-use-discard" economic model (Barros, 2019; Maab; Grundmann, 2018), the circular economy "grow-make-use-restore" (Barros, 2019; Casarejos *et al*., 2018) It is a model that aims to maintain components, materials and products with maximum utility value, with the aim of eliminating waste from a system (Barros, 2019; MacArthur, 2013).

A partial way to help solve this problem would be to use an alternative material in the manufacture of packaging. Due to its low production cost and proven excellent in biodegradability, starch constitutes a promising raw material for the production of biodegradable plastics, also called biodegradable films (Brasil, 2013).

The biofilm produced with starch can be used as packaging for food and to increase its functionality, additives can be incorporated into the polymer matrix, aiming at the interaction with the food, prolonging its shelf life or conferring desirable sensory and/or nutritional characteristics (Almeida *et al.,* 2013; Jacobs *et al*., 2020).

With this, there are some studies regarding the use of cashew waste, such as the use of cashew resin for the production of biodegradable plastic, carried out at the Federal University of Goiás(Cardoso, 2022).

As well as in another study that used cashew juice as a culture medium for bacterial cellulose (matrix) and cashew pruning residue, as a source of cellulose nanocrystals (for reinforcement) and lignin (for hydrophobization and active properties). Therefore, the lignin and cellulose nanocrystals were isolated from the cashew tree pruning fiber, and improved the tensile and barrier properties of the bacterial cellulose films (Sá *et al.,* 2020).

As well as other research related to the impact of the inclusion of cashew nutshell powder in polyvinylalcohol-based films. Therefore, these findings highlighted the possibility of combining cashew nuts (CNS) and polyvinyl alcohol to manufacture biocomposite films with higher biodegradability and antibacterial characteristics, along with higher tensile strength and thermal stability, confirming their feasibility for eco-friendly packaging materials and other sustainable applications (Mahanta; Joardar, 2024).

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

The problem of this study was to transform cashew waste (Anacardium occidentale) from the Cariri region into biodegradable films with potential for application in the food industry, contributing to the reduction of waste and the search for sustainable alternatives to conventional plastics, therefore, with this formulation it highlights the main concerns that the study addresses in relation to the use of agro-industrial waste, innovation in the production of biodegradable materials, and sustainable application in the food industry. Therefore, the present work aims to characterize biodegradable films produced from cassava starch using glycerol as plasticizer, with the addition of dehydrated organic cashew residues.

MATERIALS AND METHODS

Cassava flour was acquired as a product of the local agro-industrialization of the city of Crato-CE and region. Other ingredients such as glycerol (plasticizer, Nox Solutions), potassium sorbate (antimicrobial, Pryme Foods) was provided by the Laboratory of Food Technology and Characterization of Biocomposites of the Agronomy Course-CCAB-UFCA-Ceará-Brazil.

The residue of the industrialization of cashew originated from the local industry, was received at the Laboratory of Food Technology and Characterization of Biocomposites of UFCA-Ceará-Brazil, Figure 1, and the process of obtaining the cashew flour rich in fibers was carried out by drying (dried in a forced air circulation stove model Solab RL-102) the pseudo stem of the cashew, with subsequent grinding (portable equipment turbo max Mondial).

Figure 1. Preparation of cashew residue, drying

Preparation and characterization of the by-product of the industrialization of cashew (cashew flour). The physicochemical characterization followed the following recommendations:

- Determination of total carbohydrates (Instituto Adolfo Lutz, 2005).
- Determination of reducing carbohydrates (Instituto Adolfo Lutz, 2005).

- Determination of non-reducing glycides (Instituto Adolfo Lutz, 2005).
- Protein determination (Instituto Adolfo Lutz, 2005).
- Determination of lipids (Instituto Adolfo Lutz, 2005).
- Determination of the total caloric value (Energy, 2003).
- Determination of the ash (Instituto Adolfo Lutz, 2005).
- Determination of pH (Instituto Adolfo Lutz, 2005).
- Determination of vitamin C (Instituto Adolfo Lutz, 2005).
- Determination of calcium (Instituto Adolfo Lutz, 2005).
- Determination of the iron (Instituto Adolfo Lutz, 2005).
- Determination of phosphorus (Instituto Adolfo Lutz, 2005).

Preparation of the film-forming solution

The preparation of the film-forming solution follows the method of (Munaro, 2019) modified, where the solution is prepared from the mixture of cashew flour rich in fibers in specific concentration (reinforcing agent), potassium sorbate (antimicrobial agent), cassava flour (starch source), addition of glycerol (plasticizing agent). The preparation consisted of mixing all ingredients and brought to a temperature between 65º and 70º C for 15 minutes, under constant agitation, until reaching the moment of gelatinization. After gelatinization, potassium sorbate was added and then the solutions were spread on glass plates and taken to the oven with air circulation at 60 °C for 24 hours. The formulation and quantity of the ingredients are shown in Table 1 below:

Table 1. Ingredients and quantities used in the formulation of the biofilm

Makings	Movie Control	Film with addition of cashew flour
Starch	48.0 g	48.0 g
Glycerol	14.4 g	14.4 g
Distilled water	1600 ml	1600 ml
Sorbate Potassium	3.2 g	3.2 g
Cashew flour	0.0	2 g

Source: Author, 2023

Film characterization. In the biofilm characterization stage, the following evaluations were performed: thickness, weight, density, moisture content and permeability to water vapor (PVA).

Determination of thickness. The thickness was determined in 7 random points using a digital caliper, Kala Mark 6" Digital, the final result was obtained through the arithmetic mean of the measurements (seven random points) performed in each sample (Oliveira *et al*., 1996).

Determination of moisture content. The moisture content was determined by the method of moisture in an oven at 105ºC at constant weight, following the recommendations of (Instituto Adolfo Lutz, 2005).

Determination of weight. According to (Oliveira *et al*., 1996), the quantity and viscosity (consistency) of the film solution are factors that contribute to obtaining plastic films with greater or lesser weight, density and mechanical strength (Oliveira *et al*., 1996). Its determination, in g/cm^2, was performed after desiccator dehydration for 24 h, dividing its mass (g) by the corresponding surface (cm^2).

Determination of density. The mechanical and barrier properties of flexible films are also influenced by their density.

Determination of permeability to water vapor. The gravimetric determination of water vapor permeability (PVA) is based on the methodology (ASTM, 2000), with some adaptations. The film was fixed in the circular opening of a 125 mL capacity Erlenmeyer vial and fixed with adhesive tape to ensure that all moisture/water vapor migration occurred exclusively through the film. The inside of the Erlenmeyer flask was partially filled with distilled water (50 mL), in which the initial mass of the Erlenmeyer-water-film-tape (mi) system was measured and, in the next step, placed in a desiccator containing silica-gel.

Successive weigh-ins were performed every 2 hours during a 24-hour interval.

Statistical analysis. The statistical analysis of the results was performed with the software Statistica version 7. To compare the means, Tukey's test was performed (significance level of 5%).

RESULTS AND DISCUSSION

The films obtained appeared good, easily detached from the plates, and visually did not present bubbles or cracks, indicating that the concentration of solids in the film-forming solution (3 % w/v) used to produce the films was adequate (Figure 2).

Figure 2. Biodegradability film of cashew (anacardium occidentale) residue.

Preparation and characterization of the by-product of the industrialization of cashew (cashew flour)

The cashew pseudo fruit is considered a by-product in the industrialization of the cashew-based beverage, making it an environmental problem its disposal, as an alternative for its use, the by-product. The results of the physicochemical characterization can be seen in Table 2.

Table 2. Results of physical and chemical tests of cashew flour

Tests	Results	Units
Protein	9.35	g.100 g^{-1}(%)
Grease	3.07	g.100 g^{-1} (%)
Total carbohydrates	75.06	g.100 g^{-1} (%)
Total sugars	12.17	g.100 g^{-1} (%)
Glucose-reducing sugars (monosaccharides)	3.84	g.100 g^{-1} (%)
Non-reducing sugars in sucrose (disaccharide)	8.33	g.100 g^{-1} (%)
Calories	365.27	Kcal 100 g^{-1}
Fresna	1.44	g.100 g^{-1} (%)
Acidity	27.59	mL sol. normal 100 g^{-1}
pH	3.94	-
Calcium as Ca	12.85	mg.100 g^{-1}
Iron as Faith	<0.50	mg.100 g^{-1}

Phosphorus as P	85.72	mg.100 g^{-1}
Vitamin C	79.77	mg.100 g^{-1}

Source: Author, 2023

Elaboration and characterization of the biofilm

After grinding and obtaining the cashew flour, the ingredients were mixed hot and distributed in glass plates, which were dried in an air circulation oven. The results of the evaluated parameters are presented in Table 3.

From the data obtained it can be inferred that the films produced have a low weight, average of 2.37 g, average thickness of 0.046 cm, similar to that found by the films obtained from corn starch, and these characteristics together with the weight, 0.039 g/m², values similar to those found by da Costa, (2020), which gives it a high flexibility, making it ideal for food coating. The density found was 0.85 g/cm³, a value lower than that obtained by Costa *et al*., (2018). When working with the production of biodegradable plastic films based on bean starch, chitosan and glycerol, this parameter is also lower than the density of water, being an important parameter for its biodegradation, characterizing it as a biologically sustainable product.

Table 3. Characterization of biodegradable films

Practice	Results	Unit
Weight	2.37	g
Weight	0.039	g/ m²
Density	0.85	g/ cm³
Humidity	9.6	(%)
Solubility	27.94	(%)
Permeability	372.4	g.mm m^{-2} kPA^{-1} diameter $^{-1}$
Thickness	0.046	cm
Opacity	0.48	nm

Source: Author, 2023

The permeability found, average of 372.4 g. mm. m^{-2} kPA^{-1} $diameter^{-1}$, was also low, and this is what allows the interaction with the external environment when the product is stored and thus configures protection to the product, the solubility analysis revealed an average of 27.94%, value close to the values found by da Costa & de Oliveira, (2020), between 15-28% and 25-52%, still considered a low value, ideal for the participation of food products rich in aqueous activity, so a film with low humidity, which in this case is 9.6%, provides even more food preservation, a value similar to that found by Silva *et al*., (2021) in the production of cassava starch biofilms with propolis extracts.

Its opacity is also considerably low, about 0.48 nanometers, which is a good feature for food films, whose visual characteristics are important to see the degradation process, the value found is much lower than those found by Silva *et al*., (2021), which was between 44.3 and 65.15, where the material used made the film very dark.

CONCLUSION

Therefore, the mixture of starch and cashew flour is advantageous not only for the lower cost of starch, but because a much smaller amount of cashew flour can be used to produce films.

The films produced have little thickness and weight and are very flexible, which helps to wrap the food in different formats. Because they are poorly soluble in water, they favor the storage of products with high aqueous activity. The low permeability and low humidity of the films favor the food preservation process, minimizing the exchange of moisture with the environment. The films obtained are sufficiently translucent allowing a good visualization of the packaged material, so they presented favorable characteristics for food preservation.

Acknowledgments: The CaJuina company for supplying the raw material. The authors would like to thank Professor João Hermínio Silva for all his contributions and guidance during his lifetime and would like to express our sincere thanks.

Authors' Contributions: Palmeira, I.A.; Rodrigues R.R.F. and Machado, M.I.R.:conception and design, acquisition of data, analysis and interpretation of data, and drafting the article; Palmeira, I.A.and Machado.A.R.:acquisition of data, analysis and interpretation of data, and drafting the article; Palmeira, I.A.and Machado.M.I.R.:acquisition of data and analysis and interpretation of data; Palmeira, I.A.; Rodrigues R.R.F.: acquisition of data and analysis and interpretation of data; Duarte, C.L., Toledo, A.M.N., Machado A, R. and Machado.M.I.R.: analysis and interpretation of data and critical review of important intellectual content; Machado, M.I.R..: conception and design, analysis and interpretation of data, and critical review of important intellectual content. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

REFERENCES

ALMEIDA, D. M.; WOICIECHOWSKI, A. L.; WOSIACKI, G.; PRESTES, R. A.; PINHEIRO, L. A. Phisical, chemical and barrier properties in films made with bacterial celullose and potato starch blend. **Polymers**, v. 23, p. 538–546, 2013. https://doi.org/10.4322/polimeros.2013.038

ASTM. Standard test methods for water vapor transmission of material, E96-00. *In:* **Annual Book of ASTM Standards**. Philadelphia: American Society for Testing and Materials, 2000.

AZEVEDO, J. A Economia Circular Aplicada no Brasil: Uma análise a partir dos instrumentos legais existentes para a logística reversa. *In:* **Anais** [..] XI Congresso Nacional de Excelência em gestão. 2015.

BARROS, M. V. **Ferramenta para promover a economia circular em propriedades rurais**. 2019. Thesis [master] - Universidade Tecnológica Federal do Paraná, Curitiba, 2019. http://repositorio.utfpr.edu.br:8080/jspui/handle/1/4283

BRASIL. **Uso de materiais menos agressivos ao meio ambiente na fabricação das embalagens**. Brasilia: Ministério do meio ambiente, 2013.

BROINIZI, P. R. B.; ANDRADE-WARTHA, E. R. S. DE; SILVA, A. M. DE O. E.; NOVOA, A. DE J. V.; TORRES, R. P.; AZEREDO, H. M. C. DE; ALVES, R. E.; MANCINI-FILHO, J. Avaliação da atividade antioxidante dos compostos fenólicos naturalmente presentes em subprodutos dp pseudofruto de caju (Anacardium occidentale L.). **Ciência e Tecnologia de Alimentos**, v. 27, n. 4, p. 902–908, 2007. https://repositorio.usp.br/item/002410486.

CARDOSO, M. **Plástico biodegradável é produzido com resina do cajueiro**. Goiânia: UFG - Universidade Federal de Goiás, 2022. https://ufg.br/n/89535-plastico-biodegradavel-e-produzido-com-resina-do-cajueiro

CARIOCA, J.; ARORA, H. **Recycling process for human food and feed from residues and resources**. Fortaleza: Edições UFC/Banco do Nordeste, 2000, 428p.

CASAREJOS, F.; BASTOS, C. R.; RUFIN, C.; FROTA, M. N. Rethinking packaging production and consumption vis-à-vis circular economy: A case study of compostable cassava starch-based material. **Journal of Cleaner Production**, v. 201, p.1019–1028, 2018. https://doi.org/10.1016/j.jclepro.2018.08.114

CHENG, H. N.; FURTADO, R. F.; BISWAS, A.; ALVES, C.; PRIETO, C.; LAGARON, J. M. Chemical Modifications and Applications of Cashew Byproducts—A Selective Review. **ACS Food Science & Technology**, v. 3, n. 4, p. 546–552, 2023. https://doi.org/10.1021/acsfoodscitech.2c00168

COSTA, D. DA; SILVA, L. DA; LIMA, M. J. DA. Caracterização de blendas de amido de feijão macáçar, quitosana e glicerol. **Holos Environment**, v. 18, n. 2, p. 207-226, 2018. https://doi.org/10.14295/holos.v18i2.12290

DA COSTA, D.; DE OLIVEIRA, R. Queratina de penas de frangos nas propriedades de biofilmes de amido de milho-glicerol. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 15, n. 1, p. 57–61, 2020. https://dialnet.unirioja.es/servlet/articulo?codigo=7283558

DEBIAGI, F.; IVANO, L.; NASCIMENTO, P.; MALI, S. Starch biodegradable packaging reinforced with lignocelulosic fibers from agroindustrial wastes. **Biochemistry and Biotechnology Reports**, v. 1, n. 2, p. 57–67, 2012.

ENERGY, F. **Methods of analysis and conversion factors food and paper nutrition paper**. Rome, Italy: Food and Agriculture Organization, 2003.

INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. 4. ed. Brasília: Instituto Adolfo Lutz, 2005. p. 1018.

JACOBS, V.; SIQUEIRA SOUZA, F.; BOTELHO SOUZA HAMM, J.; SZCZESNY MANCILHA, F. Produção e caracterização de biofilmes de amido incorporados com polpa de acerola. **Revista Iberoamericana de Polímeros**, v. 21, n. 3, p. 107–119, 2020. https://dialnet.unirioja.es/servlet/articulo?codigo=7566047

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

MAAB, O.; GRUNDMANN, P. Governando transações e interdependências entre cadeias de valor ligadas em uma economia circular: O caso da reutilização de águas residuais em Braunschweig (Alemanha). **Sustentabilidade**, v. 10, n. 4, p. 1125, 2018.

MACARTHUR, E. **Towards the circular economy, economic and business rationale for an accelerated transition**. Cowes, UK: Ellen MacArthur Foundation, 2013. p. 21-34.

MAHANTA, G. K.; JOARDAR, H. Study on the Impact of Bio Waste Cashew Nut Shell Powder in the Polyvinyl Alcohol Bio Films. **Waste and Biomass Valorization**, 2024 https://doi.org/10.1007/s12649-024-02576-3

MUNARO, G. **Amido Oxidado e Colágeno na Produção de Filmes Biodegradáveis**. 2019. 38f. Trabalho de conclusão de curso (Técnico em Biotecnologia Integrado ao Ensino Médio) - Instituto Federal do Paraná, Londrina, 2019. Disponível em: Https://londrina.ifpr.edu.br/wp-content/uploads/2020/03/ Acesso em: 27 jan 2023.

OLIVEIRA, L.; ALVES, R.; SARANTÓPOULOS, C.; PADULA, M.; GARCIA COLTRO, L. E**nsaios para avaliação de embalagens plásticas flexíveis**. Campinas: Centro de Tecnologia de Embalagem, CETEA, 1996. p. 219.

PINHO, L. **Aproveitamento do resíduo do pedúnculo de caju (Anacardium Occidentale L)**. 2009. 85f. Dissertação (Mestrado) - Universidade Federal do Ceara, Fortaleza, 2009.

PINHO, L.; AFONSO, M.; CARIOCA, J.; COSTA, J.; RYBKA, A. Desidratação e aprovei amento de resíduo de pedúnculo de caju como adição de fibra na elaboração de hambúrguer. A**limentos e Nutrição**, v. 22, n. 4, p. 571–576, 2011.

SÁ, N. M. S. M.; MATTOS, A. L. A.; SILVA, L. M. A.; BRITO, E. S.; ROSA, M. F.; AZEREDO, H. M. C. From cashew byproducts to biodegradable active materials: Bacterial cellulose-lignin-cellulose nanocrystal nanocomposite films. **International Journal of Biological Macromolecules**, v. 161, p. 1337–1345, 2020. https://doi.org/10.1016/j.ijbiomac.2020.07.269

SILVA, C. N. DA; FUKUOKA, T. M.; MANHANI, M. R. Produção e caracterização de biofilmes de fécula de mandioca com extratos aquoso e alcoólico de própolis. **Revista Brasileira de Gestao Ambiental e Sustentabilidade**, v. 8, n. 19, 2021. Disponível em: http://revista.ecogestaobrasil.net/v8n19/v08n19a41a.html. Acesso em: 14 nov. 2023.

SOUZA, C. O. DE; SILVA, L. T.; DRUZIAN, J. I. Estudo comparativo da caracterização de filmes biodegradáveis de amido de mandioca contendo polpas de manga e de acerola. **Química Nova**, 35, p. 262–267, 2012. https://doi.org/10.1590/S0100-40422012000200006