I COBBIND
I CONGRESSO BRASILEIRO DE BIOTECNOLOGIA INDUSTRIAL
XXIV SINAFERM • XV SHEB • XV ENZITEC FLORIANÓPOLIS • 2024
Creating connections between biotechnology and industrial sustainability
August 25 to 28, 2024
Costão do Santinho Resort, Florianópolis, SC, Brazil
ENVIRONMENTAL BIOTECHNOLOGY

BIOCELLULOSE'S PRODUCTION APPLIED IN THE CONFECTION OF SUSTAINABLE PACKAGINGS REINFORCED WITH SUGAR CANE BAGASSE

Helen R. da Fonseca[1], Yasmim F. Cavalcanti[1], Cláudio J. G. da Silva[2], Alexandre D. Medeiros[2], Italo J. Durval[2], Andrea F. Costa[2],Julia D. Amorim[2] ,Maryana R. Santos [2], Leonie A. Sarubbo[1,2,*]

[1] *Escola Icam Tech, Universidade Católica de Pernambuco (UNICAP), Rua do Príncipe, n. 526, Boa Vista, Recife, Pernambuco 50050-900, Brasil.*

[2] *Instituto Avançado de Tecnologia e Inovação (IATI), Rua Potyra, n. 31, Prado, Recife, Pernambuco 50751-310, Brazil.*

[*] *E-mail: leonie.sarubbo@unicap.br*

ABSTRACT

The increasing demand for cellulose derivatives of plant origin has led to a rise in wood consumption as a raw material, bringing about negative environmental impacts. It is important to note that most plastics used in packaging are non-biodegradable, remaining in the environment for extended periods and continuing to threaten human health and the ecosystem. Additionally, some industries, such as the sugar and alcohol sector, generate a large amount of waste still rich in cellulose that can be utilized to produce new products. Another material that can be used in packaging production is Bacterial Cellulose (BC), a cellulose produced by bacteria. BC is biodegradable, obtained with high purity, and its production is renewable through fermentation, making it a viable and innovative option. Therefore, the present study investigated the feasibility of using BC reinforced with sugarcane bagasse (*Saccharum officinarum*) for the production of ecological packaging, revealing the significant potential of BC to replace the use of wood-extracted cellulose and reduce environmental damage caused by its management. Samples A9 and A10 stood out for their flexibility and foldability, showing potential for future analysis and validation as materials for sustainable packaging.

Keywords: Nanocellulose, Polymeric Blends, Agroindustrial Waste, Kombucha.

1 INTRODUCTION

Cellulose is widely used as a raw material. However, the increasing demand for Plant Cellulose (PC) derivatives has led to an increase in wood consumption and deforestation. Furthermore, PC contains hemicellulose and lignin, and extracting these biopolymers, contaminants of pure PC, uses environmentally harmful products. Thus, the paper and PC industries release effluents, originating from wood digestion and cellulose bleaching, which are discarded untreated or inadequately treated into the environment. [1]

Given that most plastics used in packaging are non-biodegradable, posing a threat to the environment and human health due to their slow degradation, [2] biodegradable polymers obtained from renewable sources become an attractive alternative. Therefore, sustainable solutions should consider both product formulation and packaging. Thus, creating an innovative packaging material to replace plastic and paper derived from PC becomes interesting. [3]

In this context, Bacterial Cellulose (BC) offers an innovative method for producing high-quality biodegradable packaging from renewable sources [4]. It presents advantages over PC since its fibers are nanometric, its production is carried out in reduced space, it does not depend on climatic conditions, and it does not have contaminants such as lignin, pectin, etc. [5] Its biocompatibility results in a versatile character that can be applied in the packaging industry. Additionally, the transformation process of sugarcane (*Saccharum officinarum)* in the sugar and alcohol industry results in a large volume of discarded waste, such as Sugarcane Bagasse (SB), which still contains PC and can be useful in packaging manufacturing [6] as reinforcing material [7]. Thus, the present study aims to develop the sustainable production of biodegradable packaging from renewable materials such as BC and SB.

2 MATERIAL & METHODS

Culture conditions, BC production, and Microorganisms:

For the production of BC, the microorganisms present in the Symbiotic Culture of Bacteria and Yeasts (SCOBY) deposited in the Culture Bank of the Catholic University of Pernambuco were used, transferring 10% v/v of a pre-inoculum into a cylindrical glassware. The maintenance medium consists of 10.00 g/L of green tea leaves (Camellia sinensis), 50.00 g/L of sucrose, adjusted to pH 6, and cultivated at 30°C for 14 days. The cleaning of BC was performed by washing it with running water, and purification was carried out by immersion in a 0.1 M NaOH solution at 70°C for 1 hour. According to Villarreal-Soto et al. (2018) [8], the microbiological composition present in the consortium presents bacteria and fungi. Among the microorganisms, acetic acid bacteria (*Gluconobacter sp, Acetobacter sp.),* Lactic acid bacteria (*Lactococcus sp. and Lactobacillus sp*.), and yeast (*Zygosaccharomyces bailii, Saccharomyces cerevisiae, Schizosaccharomyces pombe, Brett)* are found. The production medium consists of 10 g / L green tea (*Camellia sinensis*), 50 g / L of sucrose, 1.15 g / L of citric acid at pH 6.

Treatment of SB for packaging composition: The moist SB was purified, dried, ground in a knife mill, and then dried in an oven at 60°C for 12 hours. Subsequently, it was added to a 3% NaOH solution at 80°C for 1 hour to remove lignin and other impurities, neutralized to pH 7, and submerged in deionized water. The purified BC was triturated in an industrial blender at 18,000 rpm for 2 minutes for the packaging production. Then, the SCB was added until a homogeneous mixture was obtained. In some samples, glycerin was included due to its emollient characteristics[9]. This mass was evenly distributed on silk screens (30 cm x 20 cm) and dried.

Flexibility: Dry packaging samples were manually folded along the same point to test flexibility. The classification was based on the number of folds: poor (<20), fair (20-49), good (50-99), and excellent (>100).[10]

Percentage of Water Retention (PWR): The PWR is linked to the moisture content of the biomaterial. The wet samples were weighed and dried in the oven at 40°C until reaching a constant weight. The Water Retention Capacity (PWR) was then determined using equation 1:

$$PWR(\%) = \frac{Mean\ of\ the\ wet\ weights\ - Mean\ of\ the\ dry\ weights}{Mean\ of\ the\ wet\ weights} \cdot 100 \qquad [1]$$

3 RESULTS AND DISCUSSION

1 As shown in Table 1 below, the compositions of the samples vary in terms of the proportion of BC, glycerin, and SCB, along with the percentage rate of water retention capacity. Additionally, the samples are depicted in Figure 1.

Table 1 Composition of the samples of the material composed of BC(g), SB(g), and glycerin(ml), along with (PWR)%

Amostras	CB (g)	SB (g)	Glycerin (mL)	PWR (%)
1	200	5	10	91,7±1,5
2	200	5	5	94,4 ±1,1
3	200	2,5	-	97,0±1,2
4	200	1,5	-	97,5±0,9
5	200	1,25	5	92,9±1,5
6	200	1,5	10	92,8±1,1
7	200	1,5	5	92,4±1,1
8	200	1,5	2,5	96,5±1,2
9	200	1,5	-	98,3±1,2
10	200	1,5	-	98,5±1,3

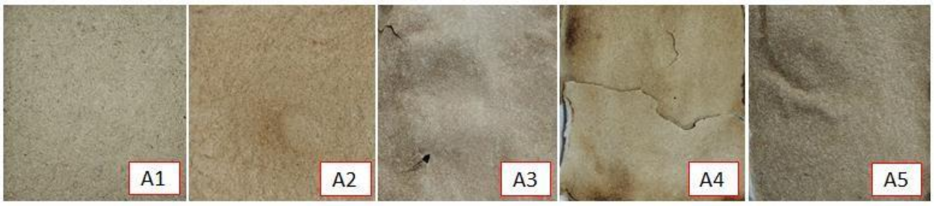

Figure 1 Samples of material for packaging confection from A1 to A5.

The samples shown in Figure 1 all had PWR above 91%, mainly due to the predominant presence of BC in them. Samples A1 and A2 weigh 17.82g and 11.99g, respectively, and exhibit excellent flexibility, supporting more than 100 folds at the same point. However, the excessive amount of glycerin in these samples results in excessive flexibility, leading to the loss of structure easily. This compromises the foldability of the material, meaning its ability to be handled and folded properly while maintaining the strength of its shape. Therefore, it is essential to balance flexibility and foldability. Samples A3 (5.98g) and A4 (5.22g) became more brittle, making further analysis impossible. One possible explanation could be temperature fluctuations in the oven. This will be investigated in further tests. Sample A5 (14.8g) exhibits excellent flexibility but has limited foldability, which may be attributed to the excess of glycerin in the sample preparation.

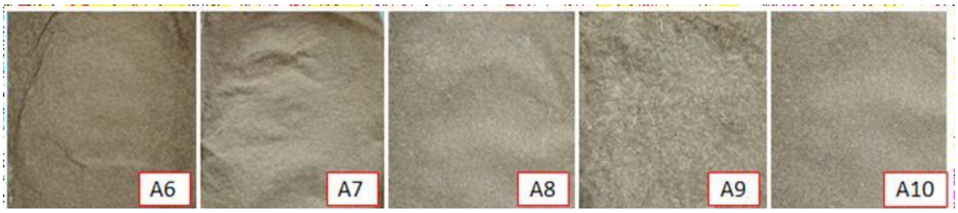

Figure 2 Samples of material for packaging confection from A6 to A10.

The samples shown in Figure 2 all had PWR above 92%. Samples A6, A7, and A8, weighing 15.21g, 14.4g, and 7.22g, respectively, demonstrated excellent flexibility, being able to be folded more than 100 times at the same point without damage due to the presence of different amounts of glycerin (10mL, 5mL, and 2.5mL), but showed low foldability due to the excess of glycerin. Samples A9 and A10, weighing 3.33g and 2.99g, demonstrated excellent foldability and the best performance. Despite slight roughness due to the SB not being properly moistened, they could be folded more than 120 times at the same point without tearing, exhibiting excellent flexibility and strength while maintaining their structural integrity after folding.

CONCLUSION

The use of BC in industrial processes can have a positive and sustainable influence. This study evaluated packaging produced from BC and SCB, highlighting their physical properties such as flexibility, foldability, and strength. The results showed that the presence of glycerin positively influenced flexibility. However, as the samples were excessively glycerinated, their ability to maintain a final shape was reduced. This relates to excessive flexibility that makes the packaging difficult to handle properly, as it does not offer sufficient resistance to maintain its shape, as observed in samples A1, A2, A5, A6, A7, and A8. Samples A9 and A10 stood out for their flexibility, foldability, and strength and will be produced on a larger scale. The y will be further analyzed to confirm their properties by Scanning Electron Microscopy (SEM) and Mechanical Tests. Additionally, Thermogravimetric Analysis (TGA) will analyze their thermal properties, and their effectiveness as biodegradable material will be validated.

REFERENCES

[1] SINGH, A.K.; CHANDRA, R. Pollutants released from the pulp paper industry: aquatic toxicityand their health hazards. Aquatic Toxicology, v. 211, p. 202-216, 2019.

[2] Plastics Europe. Plastics—the facts 2014/2015; plastics Europe—association of plastics manufacturers: Brussels, Belgium, https://www.plasticseurope.org/application/files/5515/1689/9220/2014plastics_the_facts_PubFeb2015.pdf> (2015, accessed 02 March 2024).

[3] Albuquerque RM, Meira HM, Silva ID, et al. Production of a bacterial cellulose/poly(3-hydroxybutyrate) blend activated with clove essential oil for food packaging. Polymers and Polymer Composites. 2021;29(4):259-270. doi:10.1177/0967391120912098

[4] GALDINO, C.J.; AMORIM, J.D.P; MEDEIROS, A.D.M.; CAVALCANTI, A.K.; NASCIMENTO, H.A.; HENRIQUE, M.A.; MARANHÃO, L.J.; VINHAS, G.M.; SILVA, K.K.; COSTA, A.F.; SARUBBO, L.A. Design of a naturally dyed and waterproof biotechnological leather from reconstituted cellulose. Journal of Functional Biomaterials, v. 13, n. 2, p. 49, 2022.

[5] QASIM, U.; OSMAN, A.I.; AL-MUHTASEB, A.; FARRELL, C.; AL-ABRI, M.; ALI, M.; VO, D-V. N; JAMIL, F.; ROONEY, D.W. Renewable cellulosic nanocomposites for food packaging to avoid fossil fuel plastic pollution: a review. Environmental Chemistry Letters, v. 19, p. 613-641,2020.

[6] RAJWADE, J. M.; PAKNIKAR, K. M.; KUMBHAR, J. V. Applications of bacterial cellulose and its composites in biomedicine. Applied Microbiology and Biotechnology, v. 99, n. 6, p. 2491-2511, 2015. Springer Science and Business Media LLC. http://dx.doi.org/10.1007/s00253-015-6426-3 .

[7] ALBUQUERQUE, R.; MEIRA, H.M.; SILVA, I.; GALDINO, C. J.; ALMEIDA, F.C.; AMORIM, J.; VINHAS, G.M.; COSTA, A.F.; SARUBBO, L.A. Production of a bacterial cellulose/poly(3- hydroxybutyrate) blend activated with clove essential oil for food packaging. Polymers and Polymer Composites, v. 29, n. 4, p. 259-270, 2020.

[8] Villarreal-Soto S.A., Beaufort S., Bouajila J., Souchard J.P., Taillandier P., 2018, Understanding Kombucha Tea Fermentation: a review, Journal of Food Science, 83, 3, 580-588.

[9] MILLI, B., GRIPA, D. C., & SIMONELLI, G. (2011). ALTERNATIVE APPLICATIONS OF GLYCERIN DERIVED FROM BIODIESEL. [S. l.], v. 7, n. 12. Available at: http://www.conhecer.org.br/ojs/index.php/biosfera/article/view/4584. Accessed on: Feb 10, 2024.

[10] CHEN, G.; ZHANG, B.; ZHAO, J.; CHEN, Ho. Improved process for the production of cellulose sulfate using sulfuric acid/ethanol solution. Carbohydrate Polymers, v. 95, n. 1, p. 332-337,2013

ACKNOWLEDGEMENTS

This study was funded by Programa de Pesquisa e Desenvolvimento da Agência Nacional de Energia Elétrica (ANEEL) and by the Brazilian fostering agencies Fundação de Apoio à Ciência e Tecnologia do Estado de Pernambuco (FACEPE), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) (Grant n. Finance Code 001), and performed with support from the Pernambucos Catholic University (UNICAP) and the Advanced Institute of Technology and Innovation (IATI).