IFSCC 2025 full paper (abstract reference number)

PRELIMINARY STUDY ON THE USE OF AÇAÍ (EUTERPE OLERACEA MART.) RESIDUES AS SUSTAINABLE ALTERNATIVES FOR EXFOLIATING COSMETICS

Núbia Gonçalves da Silva Pereira[1]; Pedro Augusto Laurindo Igreja Marrafa[1,2,3]; Jessica Sthefanny Carvalho Souza[1]; Fabio Roberto Passador[4]; Ernesta Malinauskyte[3]; Carlos Jose de Lima[1,2]; Adriana Barrinha Fernandes[1,2]

[1] Anhembi Morumbi University, Sao Jose dos Campos, Brasil; [2] CITE – Center of Innovation, Technology and Education, Sao Jose dos Campos, Brasil; [3] TRI – Textile Research Institute, Princeton, United States; [4] Federal University of Sao Paulo, Sao Jose dos Campos, Brasil

Abstract

The agroindustry is one of the sectors generating the highest amount of organic waste in Brazil. Often, this waste is improperly disposed of, causing significant environmental harm and limiting its potential for reuse. A prominent example is the growing global consumption of açaí, which generates substantial waste, particularly in the form of seeds that are frequently discarded inappropriately, posing environmental risks. To mitigate these impacts, the reuse of such waste—through energy generation, composting, and the extraction of high-value compounds—has explored as a promising approach. This reuse benefits the environment, and drives industrialization, employment, and income generation, although the application of açaí seeds for human consumption remains underexplored. Meanwhile, cosmetology is undergoing a "green wave," characterized by innovation driven by sustainability. Cosmetic industries are replacing synthetic materials with natural, predominantly plant-based ingredients. Advanced technologies such as nano and biotechnology are fostering the development of biocosmetics, which utilize industrial waste as raw material, creating high-value products while reducing pollutants. Given this context, this study explores the potential of açaí seeds as an alternative raw material for exfoliating products. The research focuses on micrograins derived from açaí seeds, which were processed through drying to facilitate fibrous tissue removal, followed by roasting, grinding, and particle size analysis. In study, the samples underwent characterization through Fourier-transform infrared spectroscopy (FTIR-ATR), thermogravimetric analysis (TGA), X-ray diffraction (XRD), and optical microscopy, alongside stability tests for application in cosmetic creams. FTIR analysis revealed the presence of compounds such as water, cellulose, hemicellulose, lignin, and extractives. TGA demonstrated initial weight loss due to moisture and volatiles, along with three thermal degradation events could related to hemicellulose, cellulose, and lignin, confirming the sample's thermal stability. XRD spectra indicated characteristic cellulose peaks. These findings suggest the sample exhibits good

stability for use as an exfoliating alternative, with sensory testing involving volunteers planned as the next step.

1. Introduction

The *Euterpe oleracea* Mart. (*E. oleracea*), commonly known as açaí, is a dark purple berry. Its name originates from the Portuguese interpretation of the Tupi term *yasaí*, meaning "fruit that weeps." This fruit is produced by the *E. oleracea* palm, a plant native to the Amazon Rainforest. Traditionally, the pulp of the fruit is extracted and consumed as a staple food in northern Brazil. Açaí is highly valued for its rich concentration of bioactive compounds, including essential fatty acids, polyphenols, anthocyanins, flavonoids, and tannins, all of which contribute to various health benefits when consumed regularly [1-4].

Unlike many other fruits, açaí is seldom eaten fresh. Instead, it undergoes industrial processing, where the pulp is separated, filtered, and frozen for distribution. However, this extraction process utilizes only about 15% of the fruit, leaving behind significant waste composed of seeds, fibers, and peel [5]. This substantial byproduct poses a major environmental challenge due to its large-scale accumulation, especially as açaí production has surged in recent years. Over the past decade, the production chain in the state of Pará alone expanded by approximately 15,000%, skyrocketing from 41 metric tons in 2011 to 5,937 metric tons in 2020 [6].

Although açaí fruits have been widely researched since the early 2000s [7-10], studies focusing on the industrial utilization and appropriate disposal of their seeds remain limited. Only in recent years has this topic begun to garner greater interest within the scientific community. A groundbreaking study by Rodrigues et al. [11] was among the first to analyze the phenolic composition and antioxidant activity of açaí seeds. Since then, additional research has explored their phenolic profile, as well as their antioxidant and antimicrobial properties [12-14]. Moreover, açaí seeds have been investigated for various applications, such as their use in activated carbon for metal ion removal from water [15], as biochar for soil conditioning [16,17], as an extract with potential anti-inflammatory and antioxidant effects [18, 19], and as an ecologic filler to reinforce natural rubber biocomposites [20].

Both the cosmetic industry and its consumers have increasingly shown interest in sustainable products. A sustainable development strategy must consider waste reduction and energy consumption, covering all stages of cosmetic production and use—from sourcing raw materials to the manufacturing process of cosmetic formulations. Raw materials, in particular, play a crucial role, as they significantly impact the sustainability of cosmetic emulsions [21,22]. One effective approach to resource recovery is the utilization of agro-food by-products, as many of these contain high-value bioactive compounds such as enzymes and nutrients with exceptional functionality. These valuable components can be extracted through more eco-friendly processes, leading to the production of natural oils, extracts, polymers, phytosterols, vitamins, minerals, and unsaturated fatty acids [21,23].

Thus, this study aims to evaluate the feasibility of utilizing processed açaí seed residues for conversion into microgranules for exfoliating creams. The seeds characterized in this research underwent a roasting and maceration process similar to that used in coffee powder production.

To characterize the final product, Fourier-transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), and X-ray diffraction (XRD) techniques were employed. Additionally, stability tests were conducted on cream formulations containing these microgranules.

2. Materials and Methods

The residual açaí seed samples were processed by local producers in the state of Roraima, a region within the Brazilian Amazon rainforest. To produce the artisanal açaí powder, 5 kg of sun-dried açaí were used, subjected to heating on a metal tray placed over a charcoal grill—materials commonly found in the homes of local producers. After roasting, the açaí was ground and sieved. The processed açaí was then transported to a laboratory in São Paulo city, SP-Brazil, where it underwent an additional sieving process to ensure uniform particle size distribution.

FTIR

For the analysis of processed açaí seeds, Fourier-transform infrared spectroscopy (FT-IR) with universal attenuated total reflection (UATR) was used, employing an FT-IR spectrometer (Manufacturer: Perkin Elmer, Model: Spectrum Frontier) with the Spectrum V 5.3.1 software. Analyses were performed in quintuplicate, with spectral scans of 20 samples conducted under controlled conditions: ambient temperature of 25°C, relative humidity of 46%, gain set to 1, and a resolution of 4 cm^{-1}. The resulting data provided an average spectrum for each sample.

TGA

The TGA technique was used to evaluate the stability of the samples, obtained as a function of mass loss when exposed to temperature variations. A thermogravimetric analyzer, Netzsch (Germany) model TG Q50, was used. All tests were performed with the following parameters: alumina crucible, N_2 gas purge, purge gas range of 20/2000 mg, a heating rate of 20 °C/min, final temperature of 600 °C, and sample mass of 30 mg.

XRD

The X-ray diffraction analysis was carried out using a Rigaku Ultima IV X-ray diffractometer, with radiation generated by a copper target and a verified Kα wavelength (λ = 1.54056 Å), using a nickel filter at the detector to eliminate Kβ radiation. The scanning rate was 0.2°/min, with a voltage of 40 kV, current of 30 mA, slit sizes of 10 mm/8 mm, and a 2θ angle range from 10° to 60°.

3. Results

Through FTIR analysis (Figure 1), it is possible to observe characteristic bands of plant-based materials in the sample even after the roasting and grinding process. The band at 3350 cm^{-1} corresponds to O–H stretching vibrations of cellulose and hemicellulose, with the C–H stretching vibrations (2920 cm^{-1}) closely associated with it. At 1740 cm^{-1}, a C=O stretching band appears, characteristic of carboxylic groups from lignin or hemicellulose components. The band at 1508 cm^{-1} (aromatic skeletal vibration) is a typical feature of lignin. The presence of an absorbance band in the range of 1650 to 1750 cm^{-1} further suggests the presence of

carbonyl (C=O) groups. The band at 1456 cm^{-1} corresponds to C–H deformation (methyl and methylene groups) from lignin. The band at 1313 cm^{-1} is characteristic of glucose ring stretching vibrations, indicating cellulose content [24]. The peak at 1240 cm^{-1} is attributed to C–O stretching vibrations of acetyl groups present in lignin and hemicellulose. Bands at 1062 and 1006 cm^{-1} are related to C–O stretching and C–H vibrations of cellulose, suggesting the presence of a cellulosic structure even after the roasting process. The band around 869 cm^{-1} indicates the cellulose structure due to the presence of β-glycosidic bonds in the glucose ring of cellulose [25].

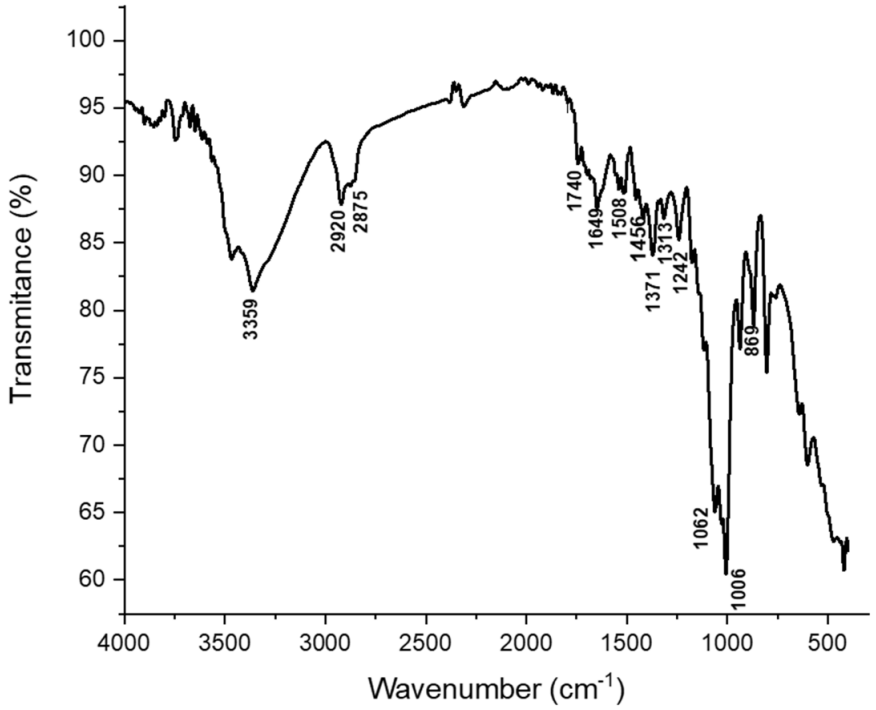

Figure 1. FTIR spectra of açai residue

The thermogravimetric curves (TGA) of the evaluated sample and its respective first derivative (DTG) are presented in Figure 2, where three stages of thermal degradation of açaí residue can be observed. The first stage occurs at around 50 °C and is attributed to moisture and water loss [26]. This behavior is common in various materials and can also be observed in cellulose extracted from different agro-industrial residues. The second stage, occurring around 285 °C, is likely related to the thermal degradation of hemicellulose and low molecular weight lignin. The third event, near 364 °C, is attributed to the decomposition of cellulose [27].

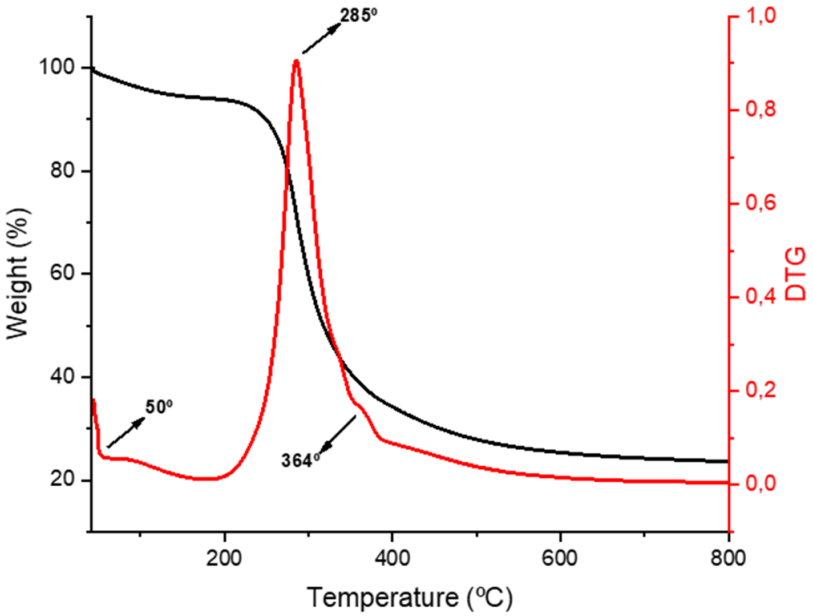

Figure 2. TGA and first derivative of TGA curves for açai residue.

Figure 3 shows the diffractogram of the açai residue, the diffraction patterns display broad peaks, suggesting a semi-crystalline structure. The reflections found between 15° and 22° are associated with crystallographic planes characteristic of the crystalline regions of cellulose, which overlap with the broader signal originating from the amorphous components, such as hemicellulose and lignin [28]. A low intensity peak at 19.4° is associated with hexagonally packed structures. Finally, the peaks at 2θ: 25° and 26.8° are commonly attributed to type I mannan, which consists of linear chains of β-1,4-linked mannose units.

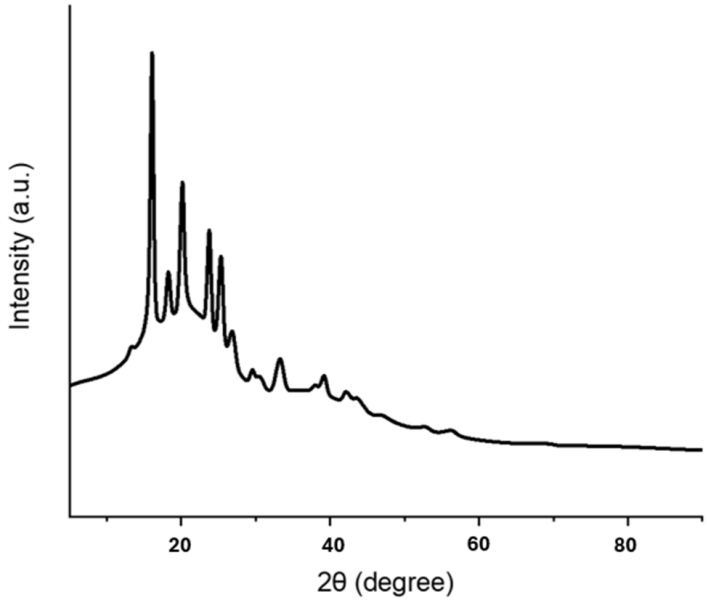

Figure 3. X-ray diffraction pattern of açaí residue.

4. Discussion

Based on the results obtained through FTIR, TGA, and XRD analyses, it is evident that the açaí residue retains important structural characteristics even after roasting and grinding processes. The presence of typical bands of cellulose, hemicellulose, and lignin in the FTIR spectrum indicates that the main lignocellulosic components were preserved. Bands associated with hydroxyl (O–H), carbonyl (C=O), and β-glycosidic bonds reveal the persistence of complex polymeric structures, which are essential for mechanical properties and chemical stability [29, 30]. This is particularly relevant for cosmetic applications, where such structures may contribute to a gentle yet effective exfoliating action, in addition to potential skin compatibility. The thermal and diffraction analyses support these structural findings. The TGA curve revealed three stages of thermal degradation, indicating the presence of moisture, low molecular weight hemicellulose/lignin, and cellulose, which demonstrates adequate thermal stability for cosmetic formulations that do not involve high temperatures. The X-ray diffraction pattern shows a semicrystalline nature of the material, with peaks typical of cellulose and the presence of type I mannan, suggesting a structural organization that may enhance its performance as an exfoliating agente [29, 31].

Lignin and hemicellulose have emerged as promising ingredients in skincare cosmetics due to their excellent biocompatibility and multifunctional properties. Lignin extracted from sugarcane bagasse has been shown to be safe for topical applications, with positive results in cytotoxicity, mutagenicity, skin sensitization, and acute irritation tests. It also demonstrated antioxidant activity, UV-blocking capacity, and antibacterial properties without compromising cell viability, especially when blended with cellulose in formulations. Nanocelluloses, including hemicellulose, offer high purity, dispersion stability, and outstanding skin compatibility, making them suitable as formulation modifiers, moisturizers, and carriers of bioactive compounds. These findings support the safe and effective use of these natural biopolymers in the development of innovative and sustainable cosmetic products [32-34].

5. Conclusion

In conclusion, the comprehensive FTIR, TGA, and XRD analyses confirm that even after roasting and grinding, the açaí residue maintains significant structural integrity, retaining its primary lignocellulosic components (cellulose, hemicellulose, and lignin) as evidenced by characteristic functional group bands and β-glycosidic linkages. These findings highlight the potential of processed açaí residue as a valuable and structurally robust ingredient for cosmetic formulations. Future research will involve sensory evaluations with volunteers to further assess its suitability for this application.

References:

1. Odendaal AY, Schauss AG. Potent Antioxidant and Anti-Inflammatory Flavonoids in the Nutrient-Rich Amazonian Palm Fruit, Açaí (Euterpe spp.). In: Polyphenols Hum Heal Dis. 2014. p. 219–39.

2. Poulose SM, Fisher DR, Bielinski DF, Gomes SM, Rimando AM, Schauss AG, et al. Restoration of stressor-induced calcium dysregulation and autophagy inhibition by polyphenol-rich acai (Euterpe spp.) fruit pulp extracts in rodent brain cells invitro. Nutrition. 2014;30:853–62.

3. Poulose SM, Fisher DR, Larson J, Bielinski DF, Rimando AM, Carey AN, et al. Anthocyanin-rich açai (Euterpe oleracea Mart.) fruit pulp fractions attenuate inflammatory stress signaling in mouse brain BV-2 microglial cells. J Agric Food Chem. 2012;60:1084–93.

4. Earling M, Beadle T, Niemeyer ED. Açai Berry (Euterpe oleracea) Dietary Supplements: Variations in Anthocyanin and Flavonoid Concentrations, Phenolic Contents, and Antioxidant Properties. Plant Foods Hum Nutr. 2019;74:421–9.

5. Martins GR, Guedes D, Marques PU, Oliveira MDSP, Lutterbach MTS, Reznik LY, et al. Açaí (Euterpe oleraceaMart.) Seed Extracts from Different Varieties: A Source of Proanthocyanidins and Eco-Friendly Corrosion Inhibition Activity. Molecules. 2021;26.

6. Santos MNL dos, Rêgo JAR do, Pantoja WN, Amaral L de NL do, Anjos EMF dos, Barreira GVC. Resíduo do açaí (euterpe oleracea Mart.): uma revisão integrativa das possíveis soluções para utilização do resíduo gerado na produção de polpa de açaí. REVISTA DELOS [Internet]. 2024;17(62):e3271.

7. Bobbio FO, Bobbio PA, Oliveira PA, Fadelli S. Stability and stabilization of the anthocyanins from Euterpe oleracea mart. Acta Aliment. 2002;31:371–7.

8. Del Pozo-Insfran D, Brenes CH, Talcott ST. Phytochemical composition and pigment stability of açai (Euterpe oleracea mart.). J Agric Food Chem. 2004;52:1539–45.

9. Schauss AG, Wu X, Prior RL, Ou B, Huang D, Owens J, et al. Antioxidant capacity and other bioactivities of the freeze-dried Amazonian palm berry, Euterpe oleraceae Mart. (Acai). J Agric Food Chem. 2006;54:8604–10.

10. Schauss AG, Wu X, Prior RL, Ou B, Patel D, Huang D, et al. Phytochemical and nutrient composition of the freeze-dried amazonian palm berry, Euterpe oleraceae Mart. (Acai). J Agric Food Chem. 2006;54:8598–603.

11. Rodrigues RB, Lichtenth¨ aler R, Zimmermann BF, Papagiannopoulos M, Fabricius H, Marx F, et al. Total oxidant scavenging capacity of Euterpe oleracea Mart. (açaí) seeds and identification of their polyphenolic compounds. J Agric Food Chem. 2006;54:4162–7.

12. Barros L, Calhelha RC, Queiroz MJRP, Santos-Buelga C, Santos EA, Regis WCB, et al. The powerful in vitro bioactivity of Euterpe oleracea Mart. Seeds and related phenolic compounds. Ind Crops Prod. 2015;76:318–22.

13. Martins GR, do Amaral FRL, Brum FL, Mohana-Borges R, de Moura SST, Ferreira FA, et al. Chemical characterization, antioxidant and antimicrobial activities of açaí seed (Euterpe oleracea Mart.) extracts containing A- and B-type procyanidins. LWT. 2020;132:109830.

14. Melo PS, Arrivetti Lde OR, de Alencar SM, Skibsted LH. Antioxidative and prooxidative effects in food lipids and synergism with α-tocopherol of açaí seed extracts and grape rachis extracts. Food Chem. 2016;213:440–9.

15. Queiroz LS, de Souza LKC, Thomaz KTC, Leite Lima ET, da Rocha Filho GN, do Nascimento LAS, et al. Activated carbon obtained from amazonian biomass tailings (acai seed): modification, characterization, and use for removal of metal ions from water. J Environ Manage. 2020;270:110868.

16. Sato MK, de Lima HV, Costa AN, Rodrigues S, Pedroso AJS, de Freitas Maia CMB. Biochar from Acai agroindustry waste: study of pyrolysis conditions. Waste Manag. 2019;96:158–67.

17. Sato MK, de Lima HV, Noronha Costa A, Rodrigues S, Mooney SJ, Clarke M, et al. Biochar as a sustainable alternative to açaí waste disposal in Amazon, Brazil. Process Saf Environ Prot. 2020;139:36–46.

18. Romao MH, de Bem GF, Santos IB, de Andrade Soares R, Ognibene DT, de Moura RS, et al. Açaí (Euterpe oleracea Mart.) seed extract protects against hepatic steatosis and fibrosis in high-fat diet-fed mice: role of local renin-angiotensin system, oxidative stress and inflammation. J Funct Foods. 2020;65:103726.

19. Santos IB, de Bem GF, da Costa CA, de Carvalho LCRM, de Medeiros AF, Silva DLB, et al. Açaí seed extract prevents the renin-angiotensin system activation, oxidative stress and inflammation in white adipose tissue of high-fat diet–fed mice. Nutr Res. 2020;79:35–49.

20. Araújo SS, Santos GTA, Tolosa GR, Hiranobe CT, Budemberg ER, Cabrera FC, et al. Acai Residue as an Ecologic Filler to Reinforcement of Natural Rubber Biocomposites. Mat Res [Internet]. 2023;26:e20220505.

21. Krzyżostan M, Wawrzyńczak A, Nowak I. Use of Waste from the Food Industry and Applications of the Fermentation Process to Create Sustainable Cosmetic Products: A Review. Sustainability. 2024;16(7):2757.

22. Park YW, Nakano Y. CE Strategy in the cosmetics Industry. In: PARK YW, TAMAKI K. Circular Economy Strategy for SDG Business Management New Theories and System Techniques. Singapore: Springer Singapore; 2025.

23. Oliveira TCG, Caleja C, Oliveira MBPP, Pereira E, Barros L. Reuse of fruits and vegetables biowaste for sustainable development of natural ingredients. Food Bioscience. 2023;53:102711.

24. Cheng, S., Huang, A., Wang, S., & Zhang, Q. Effect of different heat treatment temperatures on the chemical composition and structure of chinese fir wood. BioResources. 2016.

25. Naduparambath, S., T.V., J., Shaniba, V., M.P., S., Balan, A. K., & Purushothaman, E. Isolation and characterisation of cellulose nanocrystals from sago seed shells. Carbohydrate Polymers. 2018.

26. Moura, A., Bolba, C., Demori, R., Lima, L. P. F. C., & Santana, R. M. C. Effect of rice husk treatment with hot water on mechanical performance in poly(hydroxybutyrate)/rice husk biocomposite. Journal of Polymers and the Environment. 2017;26(6):2632-2639.

27. Poletto, M., Zeni, M., & Zattera, A. J. Effects of wood flour addition and coupling agent content on mechanical properties of recycled polystyrene/wood flour composites. Journal of Thermoplastic Composite Materials. 2012;25(7):821-833.

28. Salama, A. Cellulose/silk fibroin assisted calcium phosphate growth: Novel biocomposite for dye adsorption. International Journal of Biological Macromolecules. 2020.

29. Tavares FF da C, Almeida MDC de, Silva JAP da, Araújo LL, Cardozo NSM, Santana RMC. Thermal treatment of açaí (Euterpe oleracea) fiber for composite reinforcement. Polímeros [Internet]. 2020;30(1):e2020003.

30. Barros S de S, Oliveira E da S, Pessoa Jr WAG, Rosas ALG, Freitas AEM de, Lira MS de F, Calderaro FL, Saron C, Freitas FA de. Waste açaí (Euterpe precatoria Mart.)

seeds as a new alternative source of cellulose: Extraction and characterization. RSD [Internet]. 2021;10(7):e31110716661.

31. Murillo-Franco SL, Galvis-Nieto JD, Orrego CA. Physicochemical characterization of açaí seeds (Euterpe oleracea) from Colombian pacifc and their potential of mannan-oligosaccharides and sugar production via enzymatic hydrolysis. Biomass Conversion and Biorefnery. 2025;15:889–98.

32. Antunes F, Mota IF, Fangueiro JF, Lopes G, Pintado M, Costa PS. From sugarcane to skin: Lignin as a multifunctional ingredient for cosmetic application. Int J Biol Macromol. 2023 Apr 15;234:123592.

33. Meftahi A, Samyn P, Abbasi Geravand S, Khajavi R, Alibkhshi S, Bechelany M, Barhoum A. Nanocelluloses as skin biocompatible materials for skincare, cosmetics, and healthcare: Formulations, regulations, and emerging applications. Carbohydr Polym. 2022 Feb 15;278:118956.

34. Huët MAL, Chummun Phul I, Goonoo N, Li Z, Li X, Bhaw-Luximon A. Lignin–cellulose complexes derived from agricultural wastes for combined antibacterial and tissue engineering scaffolds for cutaneous leishmaniasis wounds. J Mater Chem B. 2024;(22).