IMPACT OF STARCH ADDITIVES ON COCONUT PALM FIBRES FOR THERMAL INSULATING PANEL APPLICATIONS.

by Jana Publication & Research

Submission date: 17-Jul-2025 12:37PM (UTC+0700)
Submission ID: 2690344191
File name: IJAR-52844.docx (1.02M)
Word count: 2413
Character count: 15851

IMPACT OF STARCH ADDITIVES ON COCONUT PALM FIBRES FOR THERMAL INSULATING PANEL APPLICATIONS.

Manuscript Info

Manuscript History
Received: xxxxxxxxxxxxxxx
Final Accepted: xxxxxxxxxxxx
Published: xxxxxxxxxxxxxxx

Key words:-
Coconut palm fibres, starch, thermal insulation, DSC, TGA, FTIR, biocomposite.

Abstract

is driving the development of bio-based thermal insulating panels. This study explores the impact of starch additives on coconut palm fibres used in the fabrication of insulating panels. A combination of Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), and Fourier Transform Infrared Spectroscopy (FTIR) was employed to analyze the thermal and structural changes induced by the starch additive. The results demonstrate that starch improves thermal stability, reduces moisture sensitivity, and enhances the degradation profile of the lignocellulosic matrix. These findings support the use of natural additives to enhance the performance and durability of biocomposite materials.

The demand for sustainable and efficient construction materials

Introduction:-

The insulating panel industry is experiencing significant growth due to increasing demands for energy efficiency and sustainable construction materials. In this context, optimizing the raw materials used in the manufacturing of these panels is a major challenge, particularly by incorporating renewable resources and enhancing their performance through specific additives.

Lignocellulosic fibers derived from plant-based sources, such as coconut palm fibers, show strong potential as base materials for producing insulating panels. Their abundance, low cost, and favorable thermal and mechanical properties make them promising candidates for industrial applications. However, improving their physical and mechanical characteristics remains a key challenge. It is in this context that the use of additives, such as starch, has garnered growing interest.

Starch, a natural biodegradable polymer, is known for its binding properties and potential effects on the cohesion and mechanical strength of fiber composites. Its interaction with coconut palm fibers could enhance the performance of insulating panels in terms of dimensional stability, mechanical resistance, and thermal efficiency. Nevertheless, the precise impact of starch incorporation on these properties remains to be thoroughly explored.

Numerous research studies have already focused on starch. Among them, the following can be highlighted:

- its application in food systems (Toutounji et al., 2019; Arp et al., 2021; Park and Kim, 2021; Shi et al., 2024);
- the effects of additives on its properties (Oluwasina et al., 2021);
- the updated concept of type 5 resistant starch (Gutiérrez and Tovar, 2021);
- the influence of glutelin on the physicochemical and structural properties of extruded starch and the underlying mechanisms (Yu et al., 2023);
- the analysis of crystalline structures of the main starch components (Rodriguez-Garcia et al., 2021) ;
- insights into the relationship between molecular structures and digestion properties of retrograded starch after ultrasonic treatment (Ding et al., 2019);

the effect of pre- and post-ultrasonication on the aggregation structure and physicochemical characteristics of tapioca starch containing sucrose, isomalt, and maltodextrin (Pourmohammadi and Abedi, 2020).

This article aims to investigate the effect of starch addition on the characteristics of coconut palm fibers used in insulating panel production. The objective is to analyze the modifications induced by this additive on the physico-mechanical and thermal properties of the final material, with the goal of optimizing its use in sustainable industrial applications.

MATERIALS AND METHODS

Materials *(Mededji et al., 2024a)*

The plant material is coconut palm fibre. These are very light fibres made up of lignins and cellulose, as shown in Figure 1. Figures 2 and 3 show, respectively, the starch used as a binder in this study and the human-powered press used for compacting to make the insulation boards.

Thermal characterisation was carried out using an experimental device built around a data acquisition unit, to which a set of heating resistors and thermocouples were connected. Data processing was carried out on a desktop microcomputer using the Excell spreadsheet program. An electronic balance was used at the start of the operation to ensure that the acceptable mass difference (0.5g) between the samples was respected.

The production equipment consists of mechanical presses manufactured in the workshop. The laboratory equipment consists of the following: apparatus (calorimetric bomb and others), solvent, reagents and glassware for thermo-physical and chemical characterisation.

Figure 1. *Various images showing coconut palm fibres*

Figure 2. *Starch* (Mededji et al., 2024b)

Methods

1) ***Preparation of the samples***

The plant waste is dried at 60-80°C to remove residual moisture, ensuring optimal conditions for subsequent processing. This step is crucial to prevent unwanted reactions during thermal analysis. The dried material

is finely ground into a powder with particles smaller than 1 mm to enhance thermal homogeneity. This uniform particle size distribution allows for consistent heat transfer and accurate measurements during analysis. Approximately 5-10 mg of the sample is precisely weighed and placed in a hermetically sealed aluminum crucible. The exact measurement ensures reproducibility and reliability in the thermal analysis process. The sealed crucible prevents moisture absorption and contamination, maintaining sample integrity.

2) DSC Analysis Parameters

The analysis is conducted under a nitrogen atmosphere to prevent oxidation. The temperature range is set from 30°C to 600°C to ensure coverage of all thermal transitions. A heating rate of 10°C per minute is applied to accurately identify thermal events.

3) Thermogravimetric Analysis (TGA) of Fibers

Prior to analysis, the plant-based waste materials are dried at 60–80°C to remove residual moisture. The dried samples are then ground into a fine powder (particle size <1 mm) to ensure thermal homogeneity during testing. Approximately 5–10 mg of the prepared material is weighed and placed in an aluminum crucible for analysis.

The analysis is conducted under a nitrogen (N_2) atmosphere to study pyrolysis behavior and assess oxidation effects. The temperature range is set from 30°C to 800°C to cover all thermal degradation stages of the material. A heating rate of 10°C per minute is applied to clearly observe thermal transitions and decomposition events. This method allows for precise monitoring of mass loss as a function of temperature, providing insights into the thermal stability and decomposition profile of the fibrous materials.

4) Experimental Protocol for FTIR-ATR Analysis of Lignocellulosic Fibers

The analysis of lignocellulosic fibers, such as palm fibers, is conducted using a Fourier-transform infrared (FTIR) spectrometer equipped with an Attenuated Total Reflectance (ATR) module. Prior to analysis, samples undergo thorough cleaning to eliminate surface impurities, dust, and contaminants that could interfere with spectral readings. For chemically or physically treated samples, the treatment is applied uniformly, followed by drying at ambient temperature in a controlled environment to ensure moisture does not distort spectroscopic results.

Instrument calibration is performed according to manufacturer specifications, including baseline verification and standard reference checks. Measurements are carried out under stable temperature and humidity conditions to minimize spectral variations caused by environmental factors. During spectral acquisition, samples are placed directly onto the ATR crystal with consistent pressure to ensure optimal contact, preventing signal distortion. Spectra are recorded in the 4000–400 cm^{-1} range at a resolution of 4 cm^{-1} (Sogbochi et al., 2024), averaging at least 16 scans to enhance data quality.

To ensure reproducibility, each sample is measured in triplicate, accounting for inherent fiber heterogeneity. Spectral data is processed using dedicated software for baseline correction, normalization, and noise reduction. Key absorption bands corresponding to cellulose, hemicellulose, lignin, and treatment-induced modifications are analyzed. Comparative evaluation between treated and untreated samples focuses on peak shifts, broadening, or new bands to assess chemical and structural changes.

This optimized protocol enables precise and reproducible FTIR-ATR characterization, supporting research on lignocellulosic fiber modifications and advancing the development of sustainable bio-based materials.

RESULTATS ET DISCUSSION

***Thermal behavior of lignocellulosic fibers by** DSC*

The thermal profile of lignocellulosic waste fibers exhibits three distinct phases. In the endothermic phase (50–150°C), a downward deviation indicates moisture evaporation, with treated fibers (1% additive, red curve) showing reduced water loss, suggesting potential hydrophilicity modification by the additive.

Between 250–350°C, biopolymer degradation occurs: hemicellulose decomposes endothermically (220–280°C), followed by amorphous/crystalline cellulose breakdown (280–350°C). The treated fibers demonstrate delayed degradation, implying additive interactions with cellulose/lignine.

The exothermic phase (450–550°C) corresponds to lignin combustion, continuing until 600°C to yield carbonaceous residue. The treated sample's smoother transition suggests modified thermal stability.

Fibrous plant waste displays characteristic thermal transitions: water evaporation, hemicellulose/cellulose decomposition, and lignin combustion. The 1% additive appears to stabilize the fibers, particularly affecting

cellulose and lignin degradation kinetics. This thermal modification shows promise for enhancing fiber performance in composite materials, bioproducts, or energy recovery applications, where improved thermal resistance is advantageous.

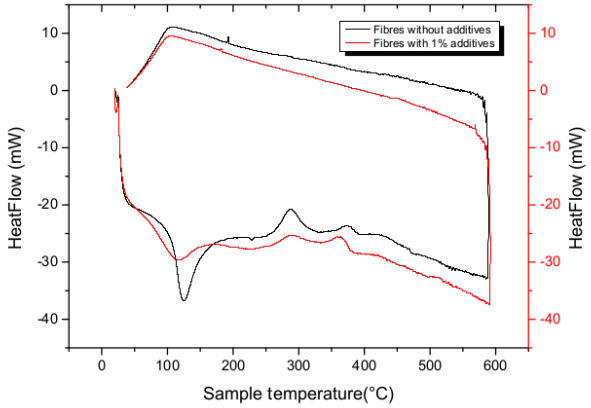

Figure 3. *DSC curves of coconut palm fibers as a function of temperature, with and without starch incorporation as an additive.*

Thermogravimetric Analysis of Lignocellulosic Fibers: Interpretation and Additive Effects

The graph displays two types of curves: Thermogravimetric Analysis (TGA, black and green curves) representing mass loss (%) as a function of temperature, and Derivative Thermogravimetry (DTG, blue and red curves) indicating thermal degradation rates and characteristic phase temperatures.

Phase 1: Moisture Loss (50–150°C): The TGA curve shows a rapid mass decrease due to free and bound water evaporation, confirmed by a distinct DTG peak. Treated fibers (green curve) exhibit lower mass loss, suggesting improved moisture retention or reduced hygroscopicity from the additive.

Phase 2: Hemicellulose Degradation (220–280°C): TGA reveals significant mass loss onset, while DTG shows a pronounced peak for untreated fibers, indicating faster hemicellulose breakdown. The additive appears to slightly stabilize hemicellulose, delaying degradation.

Phase 3: Cellulose Decomposition (280–350°C): A sharp mass drop in TGA aligns with a well-defined DTG peak for cellulose pyrolysis. Treated fibers display a less intense, shifted peak, implying additive-cellulose interactions that slow degradation.

Phase 4: Lignin Decomposition (350–600°C): Gradual mass loss in TGA corresponds to DTG's broad signal, typical of lignin's progressive degradation. Treated fibers demonstrate marginally enhanced thermal stability.

Phase 5: Carbon Residue and Final Combustion (>600°C): TGA stabilizes at a residual mass plateau, with DTG peaks absent. The additive slightly increases carbonaceous residue yield, potentially benefiting composite materials or biochar applications.

Fiber waste undergoes five-stage thermal degradation: dehydration followed by sequential pyrolysis of hemicellulose, cellulose, and lignin. The 1% additive improves thermal stability by retarding cellulose breakdown and boosting carbon residue. These findings support its use in enhancing lignocellulosic material durability for biomaterials, composites, or energy recovery applications.

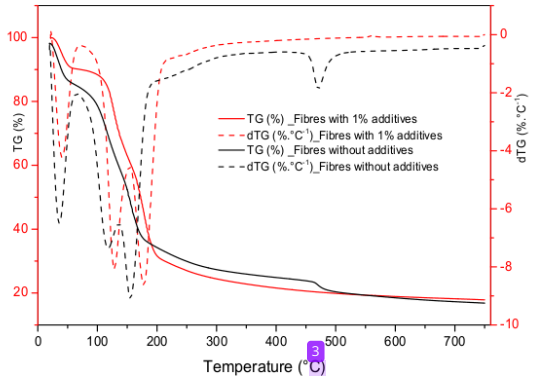

Figure 4. *Thermogravimetric analysis (TGA) and derivative thermogravimetry (dTG) curves as a function of temperature for coconut palm fibers, with and without starch added as an additive.*

FTIR-ATR spectroscopic analysis

Key spectral features must be carefully examined during ATR analysis. The broad hydroxyl (OH) stretching band near 3400 cm^{-1} indicates the presence of polysaccharides such as cellulose and hemicellulose. Aliphatic CH stretching vibrations at 2900 cm^{-1} reflect the hydrocarbon backbone of the fiber structure. Between 1500-1600 cm^{-1}, characteristic C=O and C=C absorptions reveal lignin content and phenolic compounds.

Comparative spectral analysis between treated and untreated samples provides critical insights into structural modifications. Variations in peak intensity and position may indicate chemical alterations; for instance, reduced lignin bands could suggest enhanced biodegradability or modified moisture resistance.

FTIR-ATR spectroscopy proves particularly valuable for characterizing lignocellulosic waste materials, revealing significant differences between processed and unprocessed samples. This technique provides detailed information about chemical and structural changes in key components including cellulose, hemicellulose, and lignin. The non-destructive nature of ATR allows direct examination of samples in their native state, making it an efficient tool for evaluating fiber properties. Such analysis guides the selection of optimal treatment methods to enhance fiber performance for industrial applications ranging from composite materials to textile products. The comprehensive data obtained supports the development of tailored processing approaches to improve material characteristics for specific end uses.

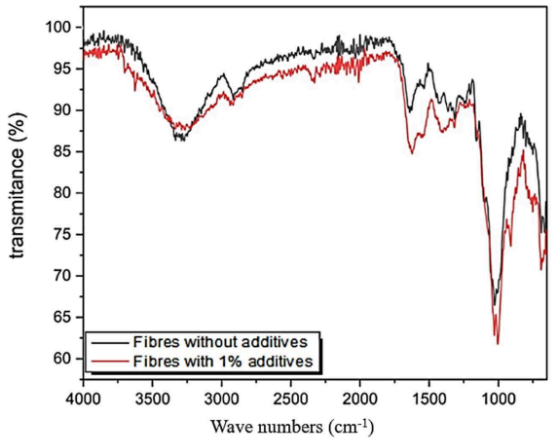

Figure 5. *ATR-FTIR spectra of coconut palm fibers, with and without starch added as an additive.*

II. CONCLUSION

Starch additives at 1% significantly enhance the thermal behavior of coconut palm fibres by reducing water sensitivity, delaying polymer decomposition, and increasing thermal residue. FTIR confirmed chemical modifications at the molecular level. These findings highlight starch's potential as a sustainable additive for improving the performance of plant-based insulating panels in eco-friendly construction.

Credit author statement

This manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

Declaration of competing interest

The authors declare that they have no conflict of interest.

III. REFERENCES

Arp, C.G., Correa, M.J., Ferrero, C., 2021. Improving quality: Modified celluloses applied to bread dough with high level of resistant starch. Food Hydrocoll. 112, 106302. https://doi.org/10.1016/j.foodhyd.2020.106302

Ding, Y., Luo, F., Lin, Q., 2019. Insights into the relations between the molecular structures and digestion properties of retrograded starch after ultrasonic treatment. Food Chem. 294, 248–259. https://doi.org/10.1016/j.foodchem.2019.05.050

Gutiérrez, T.J., Tovar, J., 2021. Update of the concept of type 5 resistant starch (RS5): Self-assembled starch V-type complexes. Trends Food Sci. Technol. 109, 711–724. https://doi.org/10.1016/j.tifs.2021.01.078

Mededji, D.S., Sogbochi, E., Djossou, A.A., Cherkaoui, O., Fagbemi, L.A., Sohounhloue, D.C.K., 2024a. Characteristics of Insulating Panels Realised from Coconut Palm Fibres for Low-Temperature Thermal Insulation. Int. J. Environ. Clim. Chang. 14, 324–335. https://doi.org/https://doi.org/10.9734/ijecc/2024/v14i54192

Mededji, D.S., Sogbochi, E., Djossou, A.A., Cherkaoui, O., Fagbemi, L.A., Sohounhloue, D.C.K., 2024b. Thermal

Insulation of “akassa” Hot Preservation Baskets Using Cow Dung Coatings. Int. J. Mater. Sci. Appl. 13, 31–40. https://doi.org/10.11648/j.ijmsa.20241303.11

Oluwasina, Olugbenga O., Akinyele, B.P., Olusegun, S.J., Oluwasina, Olayinka O., Mohallem, N.D.S., 2021. Evaluation of the effects of additives on the properties of starch-based bioplastic film. SN Appl. Sci. 3, 1–12. https://doi.org/10.1007/s42452-021-04433-7

Park, S., Kim, Y.R., 2021. Clean label starch: production, physicochemical characteristics, and industrial applications. Food Sci. Biotechnol. 30, 1–17. https://doi.org/10.1007/s10068-020-00834-3

Pourmohammadi, K., Abedi, E., 2020. The effect of pre and post-ultrasonication on the aggregation structure and physicochemical characteristics of tapioca starch containing sucrose, isomalt and maltodextrin. Int. J. Biol. Macromol. 163, 485–496. https://doi.org/10.1016/j.ijbiomac.2020.06.205

Rodriguez-Garcia, M.E., Hernandez-Landaverde, M.A., Delgado, J.M., Ramirez-Gutierrez, C.F., Ramirez-Cardona, M., Millan-Malo, B.M., Londoño-Restrepo, S.M., 2021. Crystalline structures of the main components of starch. Curr. Opin. Food Sci. 37, 107–111. https://doi.org/10.1016/j.cofs.2020.10.002

Shi, J., Mao, Y., Shi, Y.C., 2024. Effects of crystallization temperature on structure and digestibility of spherulites formed from debranched high-amylose maize starch. Carbohydr. Polym. 342, 122332. https://doi.org/10.1016/j.carbpol.2024.122332

Sogbochi, E., Balogoun, C.K., Nonviho, G., Moussiliou, S., Dossa, C.P.A., Sohounhloue, D.C.K., 2024. Synthesis of porous carbons for the fixing of cationic molecules in aqueous solution. Sci. African 25, e02332 Contents. https://doi.org/10.1016/j.sciaf.2024.e02332

Toutounji, M.R., Farahnaky, A., Santhakumar, A.B., Oli, P., Butardo, V.M., Blanchard, C.L., 2019. Intrinsic and extrinsic factors affecting rice starch digestibility. Trends Food Sci. Technol. 88, 10–22. https://doi.org/10.1016/j.tifs.2019.02.012

Yu, X., Wang, L., Zhang, J., Wang, Z., Wang, K., Duan, Y., Xiao, Z., Wang, P., 2023. Understanding effects of glutelin on physicochemical and structural properties of extruded starch and the underlying mechanism. Carbohydr. Polym. 304, 120513. https://doi.org/10.1016/j.carbpol.2022.120513

IMPACT OF STARCH ADDITIVES ON COCONUT PALM FIBRES FOR THERMAL INSULATING PANEL APPLICATIONS.

ORIGINALITY REPORT

13%	10%	8%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	ds.inflibnet.ac.in Internet Source	2%
2	www.sciencepublishinggroup.com Internet Source	2%
3	www.mdpi.com Internet Source	1%
4	koreascience.kr Internet Source	1%
5	Jing Qi, Yimin Mao, Yong-Cheng Shi. "Formation and crystalline structure of spherulites from pea and high amylose maize starches", International Journal of Biological Macromolecules, 2025 Publication	1%
6	lib.buet.ac.bd:8080 Internet Source	1%
7	pubag.nal.usda.gov Internet Source	1%
8	Submitted to University of Surrey Student Paper	1%
9	backoffice.biblio.ugent.be Internet Source	1%
10	pureadmin.uhi.ac.uk Internet Source	1%
11	link.springer.com Internet Source	<1%

12	Dilip Kumar Chandra, Awanish Kumar, Chinmaya Mahapatra. "Advanced nano-enhanced bioplastics for smart food packaging: Enhancing functionalities and sustainability", Cleaner and Circular Bioeconomy, 2025 Publication	<1 %
13	academic.oup.com Internet Source	<1 %
14	www.easdl.org Internet Source	<1 %
15	Nan Deng, Zhong Deng, Can Tang, Chengmei Liu, Shunjing Luo, Tingting Chen, Xiuting Hu. "Formation, structure and properties of the starch-polyphenol inclusion complex: A review", Trends in Food Science & Technology, 2021 Publication	<1 %
16	Submitted to UniversitÃ Telematica San Raffaele Roma Student Paper	<1 %
17	A.H. Cabrera-Ramírez, E. Morales-Sánchez, G. Méndez-Montealvo, G. Velazquez et al. "Structural changes in popped sorghum starch and their impact on the rheological behavior", International Journal of Biological Macromolecules, 2021 Publication	<1 %
18	Ahmed K. Rashwan, Hala A. Younis, Asem M. Abdelshafy, Ahmed I. Osman, Mohamed R. Eletmany, Mahmoud A. Hafouda, Wei Chen. "Plant starch extraction, modification, and green applications: a review", Environmental Chemistry Letters, 2024 Publication	<1 %

19	Xuemei Huang, Longwei Chen, Yaochi Liu. "Effects of ultrasonic and ozone modification on the morphology, mechanical, thermal and barrier properties of corn starch films", Food Hydrocolloids, 2024 Publication	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		