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Physicochemical, structural and functional properties of a protein-polysaccharide complex from cashew apple bagasse

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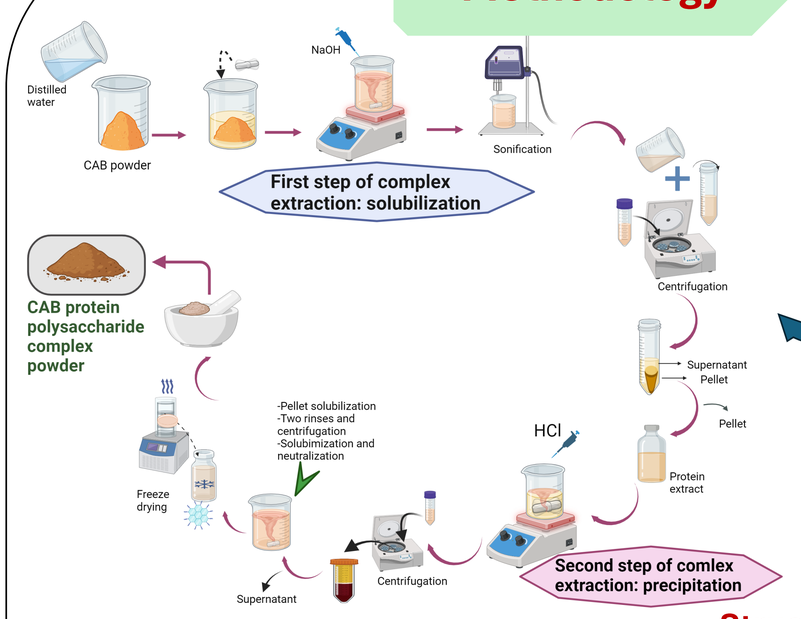
Introduction

-The cashew tree (*Anacardium occidentale* L.) is native to tropical America and is widely available in some countries of South Asia, Africa, and Central America as an economically important agricultural crop.
-The fruit has two edible parts including the cashew nut and the cashew apple (CA) which is the largest sources of residues produced by the cashew agronomic industry.
-The cashew apple bagasse (CAB), a residue underutilized of this fruit after juice extraction contains vitamins, polyphenols, sugars, minerals, amino acids, dietary fiber and proteins that can be valorized (Zié et al 2023).

Objective

To reduce food losses, increase the added value of cashew apple, and obtain new compounds and products, this study aims to characterize a novel natural protein-rich polysaccharide complex extracted from CAB (CAB-PPC). This evaluation is essential to determine its potential suitability for future use in food applications.

Methodology



Cashew apple bagasse protein-polysaccharide complex extraction process, using ultrasound

Extraction

Physicochemical characterization

- Sugar composition (GC FID)
- Surface properties (tensiometer)
- Rheological behavior (Rheometer)
- Thermal behavior (DSC on a TA Instruments)

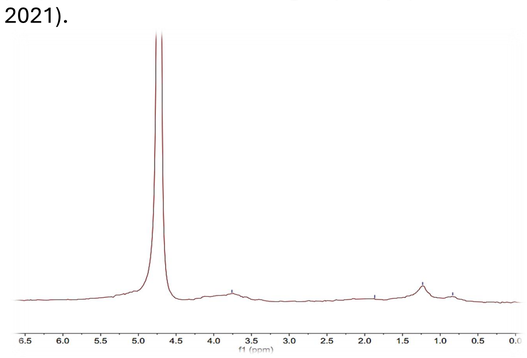
Structural analysis

- Fractions determination (HPSEC/UV-RI)
- CAB-PPC structural changes (Mid-Infrared (MIR) Fourier Transform Infrared Spectroscopy (FTIR) on the spectrometer IRTracer-100)
- NMR spectra for ^{1}H (magritek Spinsolve Benchtop 43 MHz spectrometer)

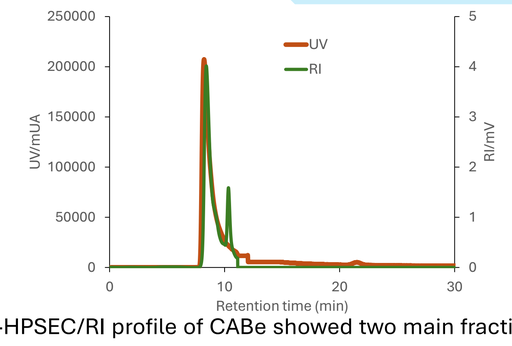
Results

Parameters	Composition, g/100g dry solids
Rhamnose	1.24 ± 0.16
Arabinose	11.85 ± 1.98
Xylose	0.69 ± 0.19
Mannose	0.77 ± 0.15
Glucose	9,79 ± 2.55
Galactose	17.45 ± 3.73
Galacturonic Acid	0.70± 0.06

-Major monosaccharides are galactose (17.45%), arabinose (11.85%) which are also predominant in cashew gum and gum Arabic (de Paula & Rodrigues, 1995) and glucose (9.79%).
-High protein percentage (22,10%) in CAB-PPC is crucial for its enhanced emulsion stabilizing capacity (Yadav et al., 2007, 2012) thickening properties, and film-forming capacity (Cai et al., 2021).



-Scanning region of CAB-PP sample 4.4–5.4 contained significant cross peaks indicating the high structural complexity of CAB-PPPC sample (Grein et al., 2013), demonstrated by FTIR analysis
-Signal from 5.01 to 4.69 ppm could be assigned to Ara, Rha and β Gal (Hay et al., 2024).
-Additional peak at 3.76 ppm was observed for 1,3-linked Gal.
-Peaks in the CAB-PPC sample, along with the presence of β-Gal, confirmed that the polysaccharide composition of CAB-PPC closely resembles that of gum Arabic.
-Gum Arabic polysaccharide typically comprised a β-(1 → 3) galactose backbone with linked branches, predominantly from C-6, but also C-4 and C-2 of Galp and Arap, terminating in Rha and GlupA.

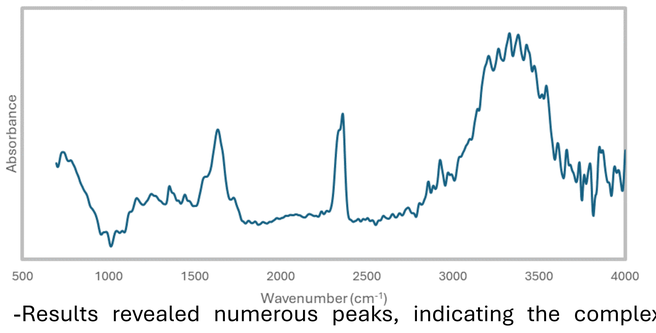


-HPSEC/RI profile of CABe showed two main fractions. The first eluted from 8-10 min, and the second eluted from 10-11 min.

-UV (280 nm) signals found in both fraction 1 and fraction 2, are attributed to the presence of aromatic amino acids.

-Proteinaceous moiety indicated a polysaccharide-protein complex (J. Lin et al., 2021).

-Major fraction (peak 1) might correspond to the arabinogalactan-protein fraction.



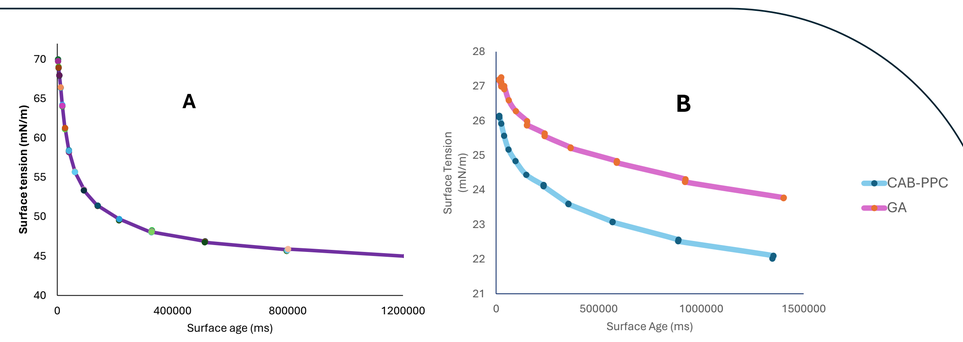
-Results revealed numerous peaks, indicating the complex structure of the extract.

-Infrared spectra of CAB-PPC exhibited similarities to those observed in gum Arabic, particularly within the peak at 3330 cm^{-1}, and the two characteristic bands at 1600-1630 and 1420-1450 cm^{-1} (Hay et al., 2024).

-Signals between 2100-2490 cm^{-1}corresponded to the structure of arabinogalactan, with vibration modes including O-H deformation + C-O stretching, CH stretch + deformation of CH2 and C-H stretch, and C-C stretch..

-Peak around 1630 cm^{-1} was ascribed to amide I and was associated with C = O stretching ; vibrational signal at 1540 cm^{-1} (amide II) was originated from N-H bending and C-N stretching.

-Peak observed at the wavelength of 1360 cm^{-1} corresponded to the structure of rhamnose (C-H stretch first overtone + CH deformation of CH3). The same peaks have been identified in gum Arabic by Dong et al. (2017). Amide III (1150 cm^{-1}) peak arisen due to the interplay between N–H angular vibration and CN stretching vibration.



-Adsorption kinetics were evaluated at the air-water (A) and sunflower oil-water interfaces (B) to assess **the colloidal behavior** of the CAB-PPC.

-Molecules were gradually adsorbed at the interface from 71 mN/m to a stable SFT value of approximately 45 mN/m.

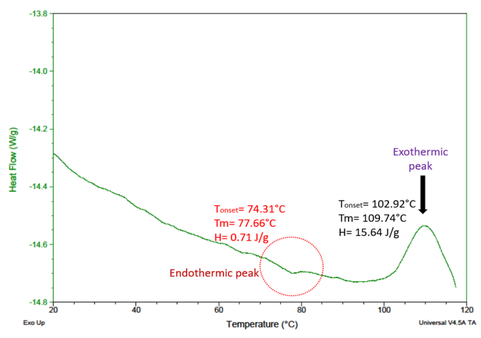
-Hay et al. (2024) and Castellani et al. (2010) showed that the surface tension of gum Arabic decreased from 72.4 to 60.1 mN/m and from 71 mN/m to 57.4 mN/m respectively, which is higher than our result.

-Hydrophilic nature combined with the more hydrophobic nature of the CAB-PPC constituents gave them a low surface tension indicating a favorable interaction between the protein and polysaccharide fractions of CAB-PPC.

-Interfacial tension decreased swiftly within the first 350 s due to the complex particles adsorbing at the oil-water interface for both gum Arabic and CAB-PPC.

-Both samples exhibited the fundamental traits of efficient emulsifiers.

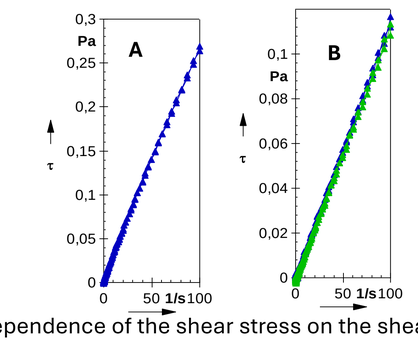
-Interfacial tension of CAB-PPC was lower than that of gum Arabic, probably due to the high protein content of CAB-PPC.



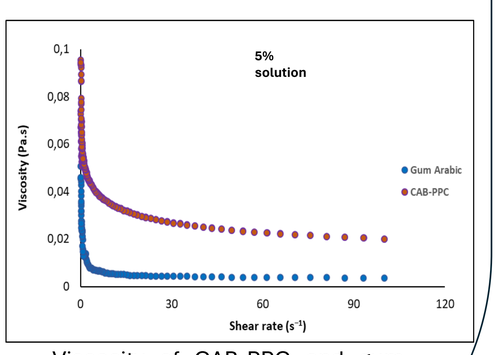
-Presence of a weak endothermic peak at 77.66°C corresponded to free protein denaturation contained in CAB-PP.

-Exothermic peak was then observed which corresponded to the decomposition of the CAB-PP powder compounds.

-Tm of CAB-PP powder (109.74°C) indicated its thermal stability.



-Dependence of the shear stress on the shear rate of CAB-PPC (A) and gum Arabic (B) solutions with increasing the shear rate from 1 to 100 s^{-1} followed by a decreasing from 100 to 1 s^{-1} => Newtonian behavior for both at 1% concentration.



-Viscosity of CAB-PPC and gum Arabic in function of the shear rate. Both complex showed a typical shear thinning behavior at 5 % concentrations.

Conclusion

- ✓ HPSEC analysis coupled with RI and UV detectors evaluated and confirmed that CAB-PPC contained two main fractions of compounds including proteins which form a complex with polysaccharides.
- ✓ For the first time, a natural protein-polysaccharide complex has been highlighted in the cashew apple.
- ✓ MIR FTIR spectroscopy and ^{1}H NMR techniques provided insights into the characteristic molecular structure of the protein-polysaccharide complex derived from cashew apple.
- ✓ Effects of protein-polysaccharide interactions within CAB-PPC on structure and functionality were investigated and showed interesting functional properties as well as their correlation relationship.
- ✓ New valuable knowledge for the first time for any application using this hydrocolloid complex, particularly in the food, pharmaceutical and cosmetic industries as a stabilizer, emulsifier and thickener.

Reference

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