DRF-592
[1-10]

RESEARCH ARTICLE
Asian Journal of Dairy and Food Research

Valorization of Plantain and Banana Biomass for Production of Sodium Carboxymethyl Cellulose

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10.18805/ajdfr.DRF-592

ABSTRACT

Background: The increasing demand for sustainable and renewable resources has prompted interest in the transformation of food/agricultural byproduct into value-added ingredients such as cellulose and its derivatives. Plantain and banana leaves and stems, constituting approximately 88% of the plant biomass, are typically discarded after fruit harvest. This study aimed to produce sodium carboxymethyl cellulose (Na-CMC) from these residues, thereby promoting sustainable development and advancing the circular economy.

Methods: Cellulose was extracted a multi-step process involving dewaxing, acid-alkali treatment and bleaching. The cellulose extracted was further converted to CMC *via* carboxymethylation using mono chloro acetic acid.

Result: Cellulose yield ranged from 16.11% in the plantain leaves to 20.77% in the banana stem, while the Na-CMC yield varied between 12.15% (plantain leaves to 16.72% (banana pseudostem). The resulting Na-CMCs degrees of substitution ranging from 0.45 to 0.57 and purity levels between 96.56% and 99.3%. Characterization using Fourier Transform Infrared (FTIR) spectroscopy confirmed successful cellulose methylation, while Scanning Electron Microscopy (SEM) revealed significant variations in their surface morphology. These findings demonstrate the feasibility of valorizing banana and plantain agricultural residues into high-purity Na-CMC, offering a sustainable alternative to wood-derived cellulose and contributing to circular economy efforts through waste minimization and resource recovery.

Key words: Banana, Cellulose, Leaves, Na-CMC, Plantain, Pseudostems, Valorisation.

INTRODUCTION

Cellulose is one of the most abundant biomasses on earth Alabi (2020) and its proper utilization holds great promise for promoting sustainable growth. As a fibrous material that constitutes a major component of plant matter, cellulose is valued for its biodegradability, durability, non-toxicity and thermal and mechanical stability. Owing to its chemical structure, a glucose polymer connected by β-1,4 linkages which crystallize in a linear configuration supported by strong intermolecular hydrogen bonds, enabling its purification and application in both food ingredients and packaging materials (Ioelovich, 2021).

Traditionally, cellulose is extracted from sources such as cotton, flax, hemp, sisal and ramie. However, a growing body of research has demonstrated the feasibility of obtaining natural cellulose fibers from agricultural residues including wheat straw, rice straw, maize husks, sorghum stalks, pineapple and banana leaves and sugarcane bagasse (Jayaprakash *et al.*, 2022; Manian *et al.*, 2021; Chopra, 2022). These typically underutilized residues, present a renewable and low-cost raw material base for value-added applications in pulp and paper, textiles, composites and particularly, functional food additives.

Among the cellulose derivatives, CMC stands out for its versatility and functionality across industrial sectors (Rahman *et al.*, 2021). CMC is produced through the partial substitution of hydroxyl groups with carboxymethyl groups (CH, -COOH) in the cellulose chain, a process catalyzed by alkali in the presence of monochloroacetic acid. It is the third most important cellulose derivative after cellulose xanthate and cellulose acetate. Depending on its purity, CMC finds applications in pharmaceuticals, detergents, cosmetics, health care and crucially, in food systems where it improves product texture, extends shelf life, preserves moisture and enhances dough rheology. Its functionality is particularly valued in bakery products, where it prevents starch retrogradation, controls sugar crystallization and

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How to cite this article: Uzoukwu, A.E., Uzomah, A., Akunna, I.C., Nnorom, O.O., Udemba, C.O., Emena, E.E., Odimegwu, E.N., Njoku, N.E. and Ofoedum, A.F. (2025). Valorization of Plantain and Banana Biomass for Production of Sodium Carboxymethyl Cellulose. *Asian Journal of Dairy and Food Research*. 1-10. doi: 10.18805/ajdfr.DRF-592.

Submitted: 18-09-2025 **Accepted:** 18-11-2025 **Online:** 01-12-2025

improves crumb structure, thereby contributing to better sensory properties and product stability (Harsono *et al*., 2021).

Commercial production of CMC primarily relies on wood pulp, creating competition with forestry resources and raising sustainability concerns (Uusi-Tarkka *et al*., 2021). This has intensified interest in exploring alternative, renewable sources of cellulose that are both economically and environmentally viable. Nigeria, being one of the world's largest producers of plantain and banana (Asogwa *et al*., 2021), generates large volumes of agricultural waste, particularly leaves and stems that represent up to 88% of the plant biomass and are mostly discarded (Tortoe *et al*., 2021). Despite their rich fibrous content and industrial potential, these residues remain largely untapped as a source of functional cellulose derivatives. The conversion of such biomass into CMC presents a compelling strategy for waste valorization, offering both environmental and economic benefits. This study, therefore, investigates the feasibility of producing carboxymethyl cellulose from plantain (*Musa paradisiaca*) and banana (*Musa acuminata*) leaves and pseudostems. The study involves the extraction and methylation of cellulose, followed by structural and morphological characterization using FTIR and SEM, as well as determination of the degree of substitution and purity of the synthesized CMC.

MATERIALS AND METHODS

The banana and plantain leaves and pseudostems used were sourced within the premises of Federal University of Technology, Owerri. All production and analytical procedures were carried out in the Food Science and Technology departmental laboratories. Chemicals and reagents used were of analytical grade and from the same department.

Time and duration of study

The study was conducted over a period of 11 months from May 2024 to April 2025, at the Department of Food Science, Federal University of Technology, Owerri.

Extraction of cellulose

Cellulose was extracted from plantain and banana pseudostems and leaves following a multi-step process shown in Fig 1. Freshly harvested pseudostems were washed, dewatered using a hydraulic press and oven-dried at 60°C for 24 hours. The dried materials were milled to pass through a 250 µm mesh. Dewaxing was carried out using a Soxhlet extractor with ethanol (1:10 g/mL, w/v) for 1 hour, followed by hexane for 3-5 hours. Acid pretreatment involved refluxing 5 g of the dewaxed powder in 0.1 M HCl (200 mL) at 70°C for 2 hours. The residue was washed, air-dried and subsequently treated with 17.5% NaOH (200 ml for 1 hour. The final bleaching step was conducted using a

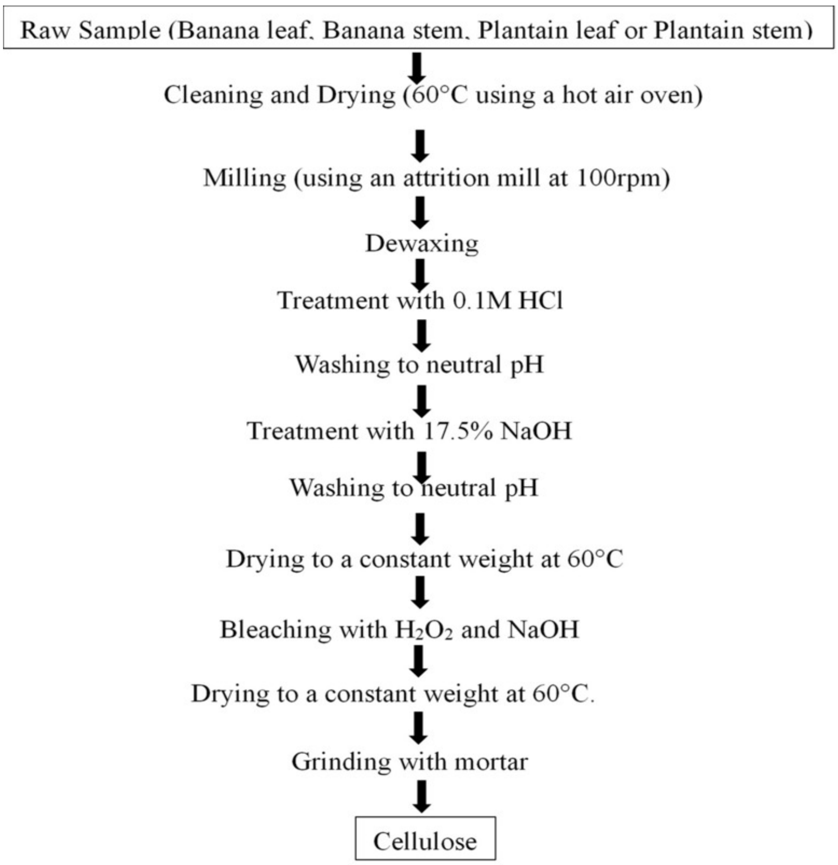

Fig 1: Extraction of cellulose from plantain and banana leaves and stems.

mixture of 20% hydrogen peroxide and 1% sodium hydroxide (2:1 ratio), heated under reflux at 50°C for 45 minutes. The bleached cellulose was filtered, repeatedly washed with distilled water and dried to a constant weight (Mohamad and Jai, 2022; Thandavamoorthy *et al.,* 2023; Zhang *et al.*, 2022).

$$\text{Cellulose yield (\%)} = \frac{\text{Weight of the bleached sample}}{\text{Weight of the original sample}} \times 100 \quad ...(1)$$

Methylation of cellulose (CMC production)

Five grams of the cellulose was weighed into a 250 ml container and 20 ml of 20% sodium hydroxide was added, followed by the addition of 100 ml of isopropyl alcohol as the solvent. The mixture was stirred for 1 hour at room temperature. Subsequently, approximately 6 g of monochloroacetate was added and the temperature was raised to 55°C for 3 hours. The resulting slurry was then filtered, treated with 90% Glacial acetic acid and washed with distilled water until a pH of 6-8 was achieved (Fig 2). The methylated sample was further washed four times in 70% ethanol and oven dried (60°C) to a constant weight (Rahman *et al.*, 2022).

Measurement of the degree of substitution (DS) of the CMC

The absolute DS values of of the CMC samples were determined following the titration method (Ofoedu *et al.*, 2021; Njoku *et al.*, 2025). About 1g of the CMC powder was stirred with 50 ml of 95% ethanol for 5 minutes. Then, 5ml of 2 M nitric acid was added and stirred further for another 10 min at room temperature. The mixture was heated to boiling for 30 min and allowed to settle. It was further filtered and washed with 95% ethanol at 60°C and 5 ml absolute methanol, followed by drying at 70°C for 3 hours. Next round 0.5 grams of the Na-CMC was mixed with 100 ml of distilled water and stirred with 25 ml of 0.5 M sodium hydroxide. Then mixture was boiled for 20 minutes and titrated with 0.3 M hydrochloric acid, using phenolphthalein as an indicator. The titration was carried out in replicate including one blank sample. The DS of CMC was determined using the following formulae.

$$A = \frac{BC - DE}{F} \quad ...(2)$$

$$\text{Degree of substitution, DS} = \frac{0.162 \times A}{1 - (0.058 \times A)} \quad ...(3)$$

Where,

A= The milliequivalents of consumed HCl per gram of specimen.

B= The volume of NaOH added.

C= The molarity of NaOH.

D= The volume of consumed HCl.

E= The molarity of HCl used.

F= The CMC in grams.

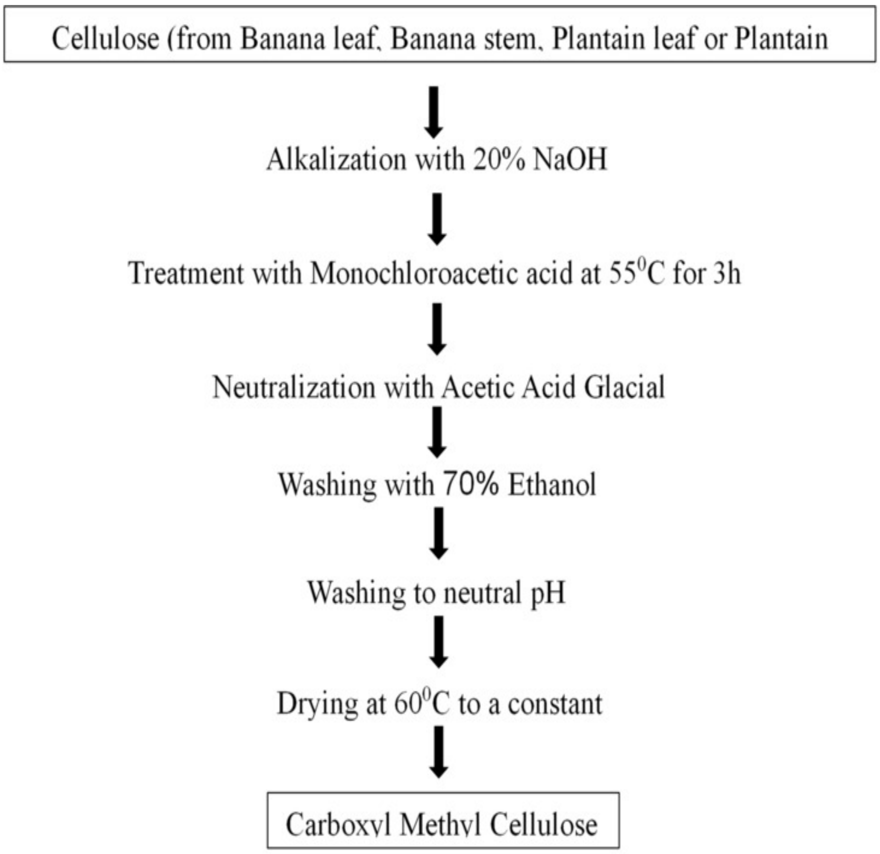

Fig 2: Methylation of the cellulose samples.

The constants, 0.162 and 0.058, represent the molecular weight of the anhydrous glucose unit and the net increment in the anhydrous glucose unit for every substituted carboxymethyl group respectively.

Percentage purity determination of the sodium carboxymethylcellulose

Purity was determined using the ethanol extraction method (Ofoedum *et al.*, 2025). One gram of dried CMC was treated with 75 ml of 80% ethanol at 60°C for 10 minutes. After filtering, the same volume of ethanol was added again and the procedure was repeated. The residue was treated with 150 ml of 80% ethanol, followed by 30 ml of 95% ethanol at room temperature. The final residue was oven-dried at 105°C for 2 hours, cooled in a desiccator and weighed. Percentage purity (S) was calculated as follows:

$$S = \frac{A \times 10000}{B\ (100 - C)} \qquad ...(4)$$

Where,

A= Mass of dried residue (g).
B= Mass of sample used (g).
C= Moisture content of the sample (%).

Fourier transformation infrared (FT-IR) analysis

FTIR spectra were recorded using an attenuated total reflection Fourier transform infrared (ATR-FTIR) spectrograph, operating within a range of 400 to 4000 cm^{-1}, with an average of 34 scans and a spectral resolution of 4 cm^{-1}.

Scanning electron microscopy (SEM)

The surface micrographs of the CMC were obtained using a scanning electron microscope (JEOL FE-JSM-7100F, Tokyo, Japan). The sample surface was coated with gold by vacuum sputter coater and the images were captured at an accelerating potential of 10 kV in different magnifications (Ardila *et al.*, 2024).

Statistical analysis

The experimental results were analysed for variance using SPSS version 20 and the mean values were separated using the Fisher's Least Significant Difference (LSD) test. Significant differences were noted at $p<0.05$ or 95% confidence level.

RESULTS AND DISCUSSSION

Cellulose yield

Table 1 shows the yield after defatting, acid/alkaline treatments and bleaching. Defatting preserved the bulk of the biomass (86.81-94.64%) with a significantly ($p<0.05$) higher value in the banana leaf (Table 1). Such high retention (>85%) is in line with observations in banana pseudostem waste, where defatting by ethanol or acetone retains over 90% of the dry mass (Bedru *et al.*, 2024). Moreover, raw banana pseudostem naturally comprises more than 50% cellulose, with the remainder largely comprising hemicellulose and lignin; Therefore, solvent extraction removes only minor extractives, preserving the polysaccharide matrix (Bampidis *et al.*, 2020). This high defatting yield establishes a solid foundation for downstream delignification, maximizing the cellulose fraction exposed to chemical treatment. Previous work on non-wood biomass confirms similar value (above 88%) in banana peels, with negligible loss of cellulosic content (Mirzaee *et al.*, 2023).

Subsequent acid and alkaline treatments retained 84.94% to 91.26% of the material (Table 1). These values closely match typical solid recoveries reported for chemical delignification of Banana Pseudostem waste. Sulfuric acid pretreatments (25% H_2SO_4) achieved up to 82% mass retention, while sodium hydroxide delignification (25% NaOH) retains around 85% of the original biomass (Nascimento *et al.*, 2023). Mohamad and Jai (2022) optimized banana stem pulping using NaOH-EDTA and reported a yield of 82.1%, indicating a similarly high solid retention under alkaline conditions. The slightly higher yields observed in this study (up to 91%) may reflect milder conditions or the inherent variability between stem and leaf tissues, with stem tissues often richer in structural polysaccharides. Such high post-delignification yields are critical as they ensure sufficient cellulose remains for subsequent bleaching and functionalization. They also demonstrate the effectiveness of the chosen acid/alkali sequence in selectively removing non-cellulosic barriers (Olawuni *et al.*, 2024; Odimegwu *et al.*, 2025).

The final bleaching step recovered significantly ($p<0.05$) higher values in the stems compared to leaves. The values obtained were: 16.11% (plantain leaf), 17.84% (banana leaf), 20.41% (plantain stem) and 20.77% (banana stem).

Table 1: Percentage yield during the cellulose extraction from banana and plantain stems and leaves.

Samples	Yield after defatting (%)	Yield after acid and alkaline treatment (%)	Yield after bleaching (%)
Plantain stem	89.77^{b}±2.79	91.26^{a}±1.27	20.41^{a}±0.41
Banana stem	86.81^{b}±1.20	87.99^{b}±0.18	20.77^{a}±1.27
Plantain leaf	88.81^{b}±0.55	84.94^{c}±0.03	16.11^{b}±0.18
Banana leaf	94.64^{a}±0.52	89.09^{b}±0.41	17.84^{ab}±2.50

Values are means of duplicate determinations±standard deviations. Means on the same column with different superscripts are significantly different at $p<0.05$. Using duncan's multiple range test (DMRT).

These figures are comparable to the 20.0% yield reported for bleached cellulose from banana pseudocore using acid/alkaline/bleaching sequences (Amaya, 2025). In contrast, TEMPO-mediated oxidation of banana pseudostem achieved a final cellulose yield of 25.25% (dried basis), reflecting a more aggressive delignification-oxidation approach that sacrifices some crystallinity for higher extraction efficiency (Nascimento *et al.*, 2023). Enzymatic hydrolysis yields are lower (within 14.58%) but offer higher crystallinity and thermal stability (Nascimento *et al.*, 2023). Hence, the 16-21% bleaching yields observed in this study sit squarely between enzymatic and TEMPO methods, which may have balanced purity and crystalline retention.

Fourier transform infrared (FTIR) of the extracted cellulose

The FTIR spectra of both banana and plantain raw leaves and stems and their corresponding extracted cellulose are shown in Fig 3. The cellulose samples closely matched that of commercial cellulose, indicating successful isolation of cellulose. All raw leaf and stem spectra displayed a broad absorption band at approximately 3300 cm^{-1}, corresponding to O-H stretching vibrations of polysaccharide hydroxyl groups and adsorbed moisture. This band remains in the extracted cellulose but with diminished intensity due to removal of non-cellulosic components (Ofoedum *et al.*, 2025). The C-H stretching region at 2900 cm^{-1} appears in both raw and purified samples, sharpening in the latter as the cellulose backbone becomes more dominant (Hozman-Manrique *et al.*, 2023). Comparable O-H and C-H bands have been reported in celluloses derived from other non-wood sources such as water hyacinth and *Agave americana* (Chaiwarit *et al.*, 2022; Krishnadev *et al.*, 2020). Notably, the stem-derived celluloses exhibit sharper and more intense O-H and C–H bands compared to their leaf counterparts, indicating a higher degree of crystallinity and lower residual hemicellulose (Ofoedum *et al.*, 2025; Bedru *et al.*, 2024).

Again, distinct peak at 1732 cm^{-1}, attributed to C=O stretching of acetyl and ester groups in hemicellulose and lignin, is evident in all raw leaf and stem spectra but vanishes entirely in the extracted cellulose, especially in the stems (Harsono *et al.*, 2021). However, only the plantain leaf cellulose retained minor absorbance near 1733 cm^{-1}. Another minor residual absorbance near 1620 cm^{-1}, associated with aromatic C=C stretching in lignin, is markedly attenuated in purified samples, further demonstrating lignin removal (Odimegwu *et al.*, 2025). At the finger print of the spectra, the 1420 cm^{-1} band, assigned to -CH, scissoring of crystalline cellulose, intensifies in the extracted samples (especially for the Banana stem) relative to raw material, reflecting an increased proportion of ordered cellulose domains (Sebayang and Sembiring, 2017). The C-H bending/CH, wagging band at 1370-1318 cm^{-1} sharpens post-extraction, consistent with enrichment of pure cellulose. An anti-symmetric C-O-C stretching band at approximately 1160 cm^{-1} remains pronounced after bleaching, confirming retention of the β-(1→4) glycosidic framework. Sharp C-O stretching bands at 1110 cm^{-1} and 1055 cm^{-1} in purified celluloses further indicate removal of hemicellulosic and lignin impurities (Sophonputtanaphoca *et al.*, 2023). The β-glycosidic linkage vibration at 894.5 cm^{-1}, diagnostic of cellulose, is evident in all four extracted samples, corroborating literature values for plant-derived cellulose (Suebsuntorn *et al.*, 2023). Similar studies on *Musa* pseudostem fractions

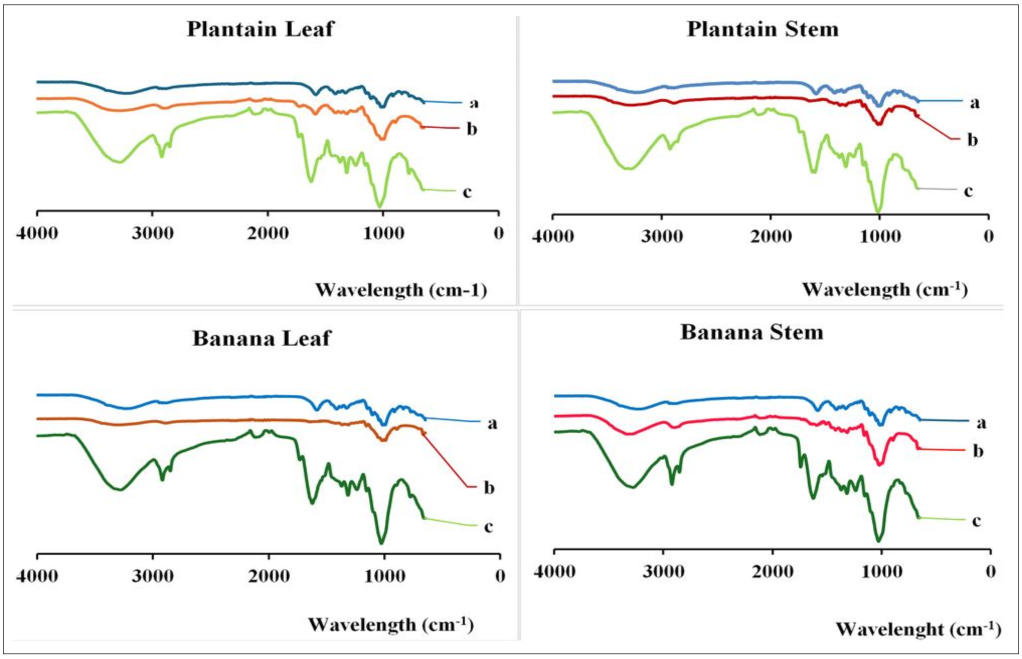

Fig 3: FT-IR spectra of the commercial cellulose (a), cellulose from the plantain and banana leaves and stems (b) and their raw samples.

demonstrated systematic decreases in lignin-related bands (1726 cm^{-1} to 1042 cm^{-1}) from outer to inner fractions, confirming the spectral trends observed here [16, 37, 39, 41]. Plantain pseudostem fibers subjected to NaOH mercerization also exhibited broad O-H bands at 3400 cm^{-1}, cellulose bands at 3335-2924 cm^{-1} and fingerprint peaks at 1325 cm^{-1}, 1033 cm^{-1} and 552 cm^{-1} (Hurtado-Figueroa *et al.*, 2025).

Properties of the Na-CMC samples from banana and plantain leaves and stems

The Na-CMC yield, Degree of substitution and purity level are presented in Table 2. Na-CMC yield of the samples which ranged from 12.5% to 16.72% (Fig 3) which is relatively low compared to values reported by other researchers Ogheneochuko and Jude (2023). Reported a yield of 135.2 for Na-CMC synthesized from rubber seed shells by mercerizing the shells with 30% NaOH solution and subsequent etherification with monochloroacetic acid. El-Sakhawy (2018) reported a Na-CMC yield as high as 185.3% from sugarcane bagasse using 40% NaOH. These lower yields in the present study are largely influenced by the cellulose source and the chemical treatment conditions.According to previous reports, the Na-CMC yield increases with an increase in the concentration of NaOH and the optimum concentration is at 20-40% (Rahman *et al.*, 2022). As the NaOH concentration increases, the medium becomes more alkaline, replacing the hydroxyl group and increasing the total mass of Na-CMC (Ibikunle *et al.*, 2019).

The DS of Na-CMC refers to the average number of the hydroxyl group (-OH) in the cellulose structure that are replaced by carboxymethyl groups (Sunardi *et al.*, 2017). DS value is one of the most important characteristics of the Na-CMC and it can be used to predict the solubility and viscosity of the Na-CMC. According to Suebsuntorn and Jirukkakul (2023), a higher DS correlates with greater viscosity and cation exchange capacity. Additionally, DS values in the range of 0.2 to 1.5 are accepted for commercial Na-CMCs and can be utilized in the food and pharmaceutical industries (Bampidis *et al.*, 2020). In this study, the DS values of the samples, which range from 0.45 to 0.57 (Fig 4), show that the Na-CMCs from the plantain and banana leaves and stems are slightly soluble in water. Thus, they can be considered a potential ingredient for various use in the food and pharmaceutical industries. The DS of Na-CMCs are usually affected by the concentration of the NaOH and the quantity of monochloroacetic acid used for methylation. The substitution degree increases with an increase in concentration of NaOH or the monochloroacetic acid up to an optimum level (Adinugraha and Marseno, 2005). El-Sakhawy *et al.* (2018) recorded the highest DS value (1.1) for sugarcane bagasse at NaOH concentration of 40% while Ofoedu *et al.* (2021) reported 1.2 g as the optimum quantity of monochloroacetic acid for obtaining the highest DS value from *Eleocharis dulcis.*

The purity levels of the Na-CMCs obtained from this study ranged from 96.56% to 99.3% and showed a

Table 2: Yield, degree of substitution and purity level of the synthesized CMC.

Samples	CMC yield (%)	Degree of substitution	Purity (%)
Plantain stem	16.72±0.26[a]	0.53±0.04[a]	98.90±0.14[ab]
Banana stem	15.87±0.23[b]	0.57±0.06[a]	96.56±0.36[c]
Plantain leaf	12.15±0.20[d]	0.53±0.03[a]	98.06±0.27[b]
Banana leaf	14.79±0.33[c]	0.45±0.04[a]	99.30±0.61[a]

Mean values on the same column with different superscripts are significantly different at $p<0.05$.
Duncan's multiple range test (DMRT).

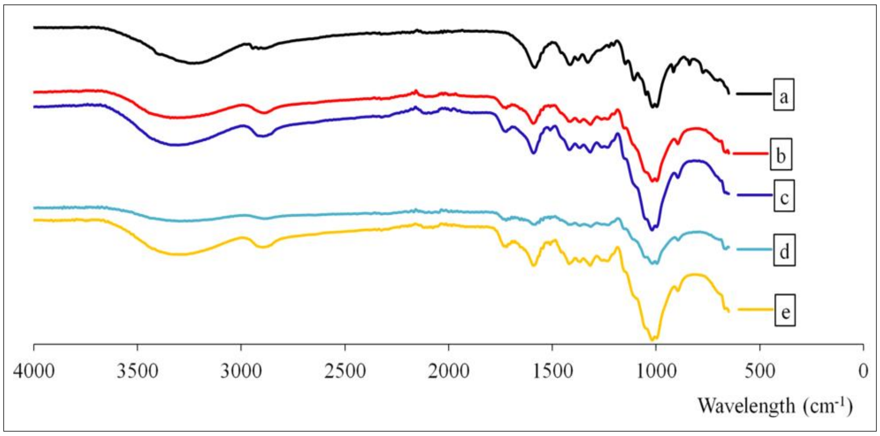

Fig 4: FTIR spectra of (a) the Commercial Na-CMC (b) Banana leaf Na-CMC, (c) Banana stem Na-CMC, (d) Plantain stem Na-CMC and (e) Plantain leaf Na-CMC.

significant difference. These values are considerably high when compared to reports from other researchers (Adinugraha and Marseno, 2005). However, a little more purification is necessary to obtained a food grade purity level of 99.5% as recommended by the Food and Agriculture Organization (Alabi *et al.*, 2020). This further purification can be accomplished by treating them with methanol or acetone to enhance the separation of Sodium chloride and Sodium glycolate (Amaya, 2025).

FTIR of the Na-CMC samples

The FTIR spectra of Na-CMC derived from banana leaf, banana stem, plantain leaf and plantain stem closely resemble that of commercial Na-CMC, confirming their structural similarity (Fig 3). However, minor differences in peak intensities or slight shifts may reflect variations in the degree of substitution (DS) or impurities from the source materials. The spectra of each Na-CMC sample exhibited characteristic asymmetric $-COO^-$ stretching bands around 1600 cm^{-1} and symmetric $-COO^-$ bands at around 1420 cm^{-1}, indicating effective etherification (Gieroba *et al.*, 2023). The intensity of the asymmetric $-COO^-$ stretching bands varied among the samples, with banana stem Na-CMC showing the strongest absorption, followed by plantain leaf, banana leaf and plantain stem. This suggests differences in the degree of substitution (DS) and local substitution patterns (Riaz *et al.*, 2018). The broad O-H stretching band at 3330-3345 cm^{-1} was most attenuated in plantain stem Na-CMC, indicating highest hydroxyl substitution (Sebayang *et al.*, 2017).

The variations in $-COO^-$ band intensity and position correlate with known relationships between FTIR peak characteristics and functional performance. Higher asymmetric $-COO^-$ intensities are associated with increased DS and enhanced water-binding capacity (Ren *et al.*, 2024). Thus, banana stem Na-CMC, with its pronounced asymmetric $-COO^-$ band, is expected to deliver superior viscosity enhancement and moisture retention (Diem *et al.*, 2023). In contrast, banana leaf Na-CMC's slightly lower $-COO^-$ intensity may favour film-forming and sensory attributes, making it a promising candidate for surface-coating applications (Ren *et al.*, 2024).

Again, the broad O-H stretching vibration band between 3200 and 3400 cm^{-1}, the C-H stretching vibration peak in the 2900 cm^{-1} region and the strong C-O-C and C-O stretching bands in the 1200-1000 cm^{-1} region were all consistent with the cellulose structure. These findings suggest that the cellulose backbone was retained in all Na-CMC samples, despite differences in source material and carboxymethylation, which is crucial for maintaining the structural and functional properties of the Na-CMC samples.

Scanning electron microscopy of the CMC samples from banana and plantain leaves and stems

The Scanning Electron Microscopy (SEM) micrographs of the samples as shown in Fig 5 illustrate homogenous films with fewer exposed fibril edges, indicating intensive substitution of surface hydroxyls by hydrophilic carboxymethyl groups (Sophonputtanaphoca, 2023). Banana leaf Na-CMC presents continuous sheet-like structures with occasional micron-scale wrinkles, suggesting strong interchain hydrogen bonding among carboxymethylated chains (Mirzaee *et al.*, 2023). In contrast, banana stem Na-CMC exhibits irregular, porous aggregates of fused particles, reflecting partial preservation of underlying microfibrillar bundles entwined in CMC clusters (Meraj *et al.*, 2025). Plantain leaf Na-CMC shows a hybrid morphology: slender residual fibrils embedded in a continuous CMC matrix, implying incomplete shielding of the cellulose backbone and potential for enhanced moisture retention through capillary action (Saberi *et al.*, 2023). Finally, plantain stem Na-CMC retains distinct microfibril bundles bridged by amorphous CMC gel layers, which may provide a balance of structural reinforcement and hydration capacity in food systems (Meraj *et al.*, 2025; Riaz *et al.*, 2018).

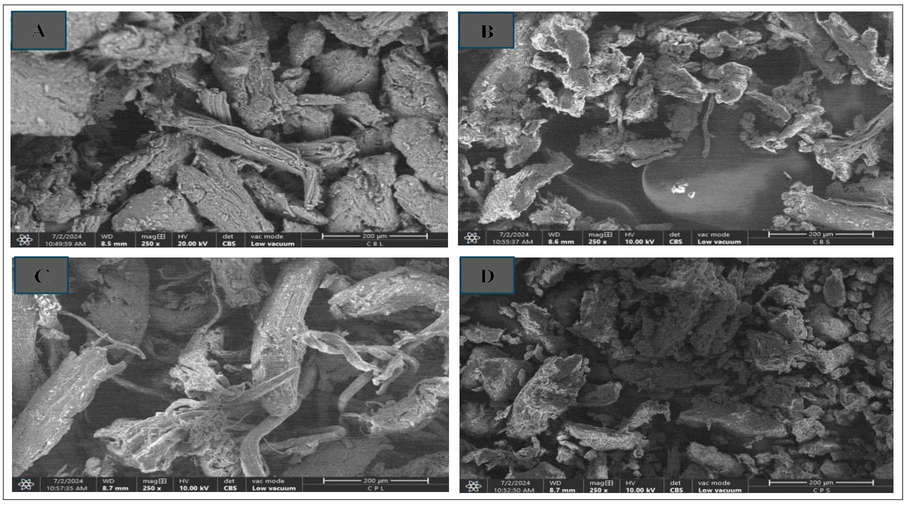

Fig 5: SEM of the Banana leaf Na-CMC (A), Banana stem Na-CMC (B), Plantain leaf Na-CMC (C), Plantain stem Na-CMC (D).

These morphological differences have direct implications for functionality in food systems. Smoother, film-forming CMC surfaces enhance solubility and reduce crystallinity, factors known to increase water-binding capacity and viscosity. Porous, aggregated morphologies, as seen in banana stem Na-CMC, offer greater specific surface area, promoting stronger interactions with other food microstructures (Diem *et al*., 2023; Ardila *et al*., 2024). The hybrid fibril-matrix architectures in plantain leaf and stem Na-CMC suggest dual functionality: residual fibrils provide mechanical support, while the surrounding CMC network delivers moisture retention and viscosity control (Cukrowicz *et al*., 2020).

CONCLUSION AND RECOMMENDATIONS

This study confirmed banana and plantain agricultural waste as sustainable sources of Carboxymethyl Cellulose (CMC), with banana stems yielding the purest cellulose (20.77%) and plantain stems achieving the highest CMC conversion (16.72%). FT-IR confirmed successful carboxymethylation, with banana stem CMC achieving the highest degree of substitution (0.57) and banana leaf CMC the highest purity (99.3%). SEM analysis revealed banana stem CMC's porous morphology and plantain stem CMC's fibril-gel matrix, which directly influenced functionality in food systems. Further research should explore industrial production and application of banana and plantain leaves and stem Na-CMCs as food hydrocolloids in food systems.

Conflict of interest

All the authors have declared that there were no conflicts of interest as well as any external funding for this research.

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