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Physicochemical Properties of Cellulose extracted From Hom Thong Banana Peels

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Abstract

Bananas are one of the most popular fruits in the world, yet only around 12% of them are consumed, posing an environmental problem. The goal of this research is to extract Hom Thong banana cellulose, which is the major component of banana peels. Fat analysis was used to extract and bleach Hom Thong banana cellulose, followed by soaking in 15% hydrogen peroxide for 3 h. The Hom Thong banana peel cellulose was washed and dried at 60 °C for 10 h. The obtained Hom Thong banana cellulose was characterized in terms of fatty acid profile, intermolecular interactions, and thermal analysis by using gas chromatography, FT-IR, and DSC techniques, respectively. The results showed that the content of palmitic acid (C16:0) in the post-evaporated ethanolic extract is larger than in pre-evaporated ethanolic extract, with a ratio of 44.91% and 38.62%, respectively. At a ratio of 26.19% and 31.56%, the post-evaporation of the ethanolic extract contained less linoleic acid (18:2cis) than the pre-evaporation of ethanolic extract. Intra-molecular interactions between OH groups of cellulose were shown by FT-IR spectra. DSC thermograms revealed that the extracted cellulose had good thermal characteristics and was appropriate for the food and cosmetic industries.

Keywords: *Hom Thong banana peel, Cellulose, Fatty acid profile, Bleaching*

INTRODUCTION

Banana is one of the world's most favorite fruits, accounting for 40% of all fruit commerce. Due to Thailand's geographical advantage and favorable environment, banana is one of the most significant fruits exported. Specifically, the Hom Thong Banana (*Musa acuminata*, AAA group) is a Thailand geographical indicator or GI (Geographical Indication) (Amnuaysin et al., 2020). There is a lot of cultivation in many provinces such as Chanthaburi, Kanchanaburi, Suphan Buri, Nakhon Sawan, Kamphaeng Phet, Bueng Kan, Phatthalung and Chumphon. Groups of countries that import bananas from Thailand are China, the United Kingdom, Japan, and the United States, and ASEAN. In addition, bananas are also processed into various products to add value, such as banana chips, salted bananas, butter bananas, and unsweetened bananas, allowing the market has expand rapidly both in Thailand and abroad. As a result, farmers are more interested in cultivating bananas. However, the edible section of the banana only accounts for 12% (w/w) of the plant,

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posing an environmental issue. One approach is to convert banana peels into cellulose, which is a more valuable product that might be used more broadly in the food industry. The goal of this study was to extract cellulose from Ham Thong banana peels and test its functional properties in food and cosmetic applications.

LITERATURE REVIEW

Forest wastes, agricultural residues, algal waste, and industrial byproducts can all be used to make cellulose (Yu et al., 2021). Banana peel is one of the abundant cellulose sources from fruit waste. From the processing of banana products, the banana peels (35-40% of all bananas) will be leftover, which is an agricultural waste. Many studies have shown that banana peels contain many chemical constituents, including cellulose (75%), carbohydrates (53%), fiber (34%), proteins, fats, and also antimicrobial agents, antioxidants, etc. (Tibolla et al., 2018). Therefore, processing waste banana peels into value-added materials from local sources should be cheaper than importing materials from abroad.

Banana peels are known as a source of lignocellulose, with varying main amounts of cellulose, hemicellulose, and lignin, depending on the plant species. Cellulose, the major component of plant fiber cell walls, is a glucose polymer with β-1, 4 glycosidic bonds, resulting in great structural complexity owing to intermolecular hydrogen bonding interaction (Veeramachineni et al., 2016, Tibolla et al., 2014). Furthermore, hemicellulose, an insoluble heteropolysaccharide, is made up of monosaccharides such as xylose, mannose, fructose, galactose, glucuronic acid, and arabinose that bind to glycosidic links in the polysaccharide backbone directly or by branching. When cellulose and hemicellulose interact with lignin, more complexation or crystalline form is produced (Palacios et al., 2017). Cellulose has been useful for many applications with natural, renewable, and biodegradable properties. It has a high degree of crystallinity, as well as good mechanical strength and stiffness.

RESEARCH METHODOLOGY

Materials

Hom Thong bananas (Musa acuminata) were obtained from the market in Pathum Thani, Thailand. Hydroxyl ethylcellulose (HEC), methanol, n-hexane, dichloromethane, and potassium chloride were obtained from Merck (Darmstadt, Germany). Boron trifluoride-methanol purchased from Sigma-Aldrich (Switzerland). Methyl-2-hydroxyethyl cellulose (MHC), hydroxypropyl methylcellulose (HMC), sodium chloride, and the supelco 37 Component FAME Mix purchased from Sigma-Aldrich (St. Louis, MO, USA).

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Hom Thong banana cellulose preparation and fat extraction

Fresh Hom Thong banana peels with a maturity rating of 7 (a yellow peel with a few brown spots) were cut into 0.3 x 2.5 cm pieces and then dried in a hot air oven at 55 °C for 10 h (Singanusong et al., 2014). Banana peel samples (3 g) were placed in a screw cap tube, and then 10 ml of methanol/dichloromethane (1:2 v/v) was added before the sample tubes were left for 1 h. The samples were filtered using Whatman filter paper no. 1, and then 0.1 M potassium chloride (approximately 20% of total volume) was added to the samples, which were then combined and centrifuged at 2,000 rpm for 10 min at 25 °C. For the methylation reaction, the lower phase of the organic solvent was collected.

a) Methylation

200 µL of the lipid samples in the screw cap tube were added 1 ml of 0.5 M NaOH-methanol, then mixed and Boiled at 100 °C, for 15 min, followed by adding 2 ml of 14% BF_3/methanol. The samples were then heated at 100 °C for 1 min before being cooled to room temperature. In addition, 500 µl of hexane and 5 ml of saturated NaCl solution were added to the samples and then centrifuged at 1,000 rpm for 5 min. Finally, the upper phase was pipette into a vial for gas chromatography analysis. (Lepage and Roy, 1984, Lepage and Roy, 1986).

b) General experimental condition

Gas chromatograph-mass spectrometer (GC-MS) (Thermo scientific®, Model Trace 1310, ISQ 7000, Sci Spec company limited). The capillary column used was TR-FAME; length: 30 m, i.d.: 0.25 mm, and film: 0.25 µm. The analysis conditions for GC-MS were set as follows: carrier gas: helium (1 ml/min), flow rate: 1.0 ml/min, detector temperature: 240 °C, column temperature: 240 °C, injector temperature: 240 °C, split ratio: 15, split flow: 18 ml/min, running time: 16 min, starting temperature was 30 °C, then increased to 240 °C with a final hold at 240 °C for 3 min. The analysis parameters of the mass spectrometry detector were: ion source temperature: 200 °C, mass spectrometry transfer line: 220 °C (Mordi et al., 2016).

c) Bleaching of the Cellulose

The defatted and protein-free banana peel powder was soaked in 15% of hydrogen peroxide solutions for 3 h. The bleached samples were washed in triplicate with distilled water, separated using Whatman paper No. 4, and finally dried for 10 h in a hot air oven at 60 °C (Singanusong et al., 2014).

Properties of Hom Thong Banana Cellulose

a) Fourier-transform infrared spectroscopy (FT-IR) Analysis

FT-IR analyses were recorded on a FT-IR spectrophotometer (HTS-XT, Sensor II, Bruker, Karlsruhe,

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Germany) equipped with a universal attenuated total reflectance device. FT-IR analysis was performed in the infrared region, with 16 scans in wavenumbers ranging from 4,000 to 400 cm^{-1} and spectral resolution of 4 cm^{-1}.

b) Differential scanning calorimetry (DSC) Analysis

A differential scanning calorimeter (Thermo plus Evo2, Rigaku, Japan) was performed to determine the thermal characteristics of the materials. Each sample (4.0-5.0 mg) was accurately weighed into aluminum pans, and an empty pan was utilized as a reference. The scan speed was set at 10 °C/min from room temperature to 450 °C. The DSC analyses were carried out three times.

FINDINGS AND DISCUSSION

Hom Thong banana peel has brownish yellow color after fat extraction and bleaching process. Fatty acid profile of Hom Thong banana peel in ethanolic extract of both pre-and post-evaporation was analysed by using a gas chromatograph-mass spectrometer. The result in table 1 showed that post-evaporation of the ethanolic extract contained a higher amount of palmitic acid (C16:0) than Pre-evaporation of ethanolic extract at the ratio of 44.91% and 38.62%, respectively. Post-evaporation of ethanolic extract had a lower amount of linoleic acid (18:2cis) than pre-evaporation of ethanolic extract at the ratio of 26.19% and 31.56 %, respectively. Besides, α-linolenic acid (C18:3n3) was also found at the ratio of 19.94% and 8.12%, respectively (Mordi et al., 2016, Erdogan Orhan et al., 2008). Evaporation of a minor fatty acid might result in a difference in the fatty acid content of ethanolic extracts. Furthermore, the number of fatty acids in the Hom Thong banana peel changed with age. Palmitic acid content increased as the fruit matured, whereas linoleic and linolenic acids were greatest in stage 2 of fruit development. They, however, gradually decreased as the fruit matured (Khawas et al., 2016).

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Table 1. Fatty acid profile from pre-and post-evaporation of ethanolic extracts of Hom Thong banana peel

Pre-evaporation						**Post-evaporation**					
Compound		**1**	**2**	**3**	**mean**	**Compound**		**1**	**2**	**3**	**mean**
1	C12:0	-	3.51	8.28	3.93	1	C12:0	1.07	0.76	0.31	0.71
2	C14:0	0.07	2.03	3.89	2.00	2	C14:0	1.23	1.08	0.81	1.04
3	C16:0	13.03	54.99	47.85	38.62	3	C16:0	49.83	47.59	37.31	44.91
4	C16:1	0.07	-	-	0.07	4	C16:1	-	-	0.27	0.09
5	C17:0	0.07	-	-	0.07	5	C17:0	-	-	0.38	0.13
6	C18:0	3.06	3.16	4.18	3.47	6	C18:0	2.78	2.85	2.78	2.80
7	C18:1 cis	24.65	5.29	6.38		7	C18:1 cis	3.06	3.08	4.16	3.43
8	C18:2 cis	55.17	20.67	18.84	31.56	8	C18:2 cis	25.05	24.95	28.58	26.19
9	C18:3 n6	0.17	-	-	0.06	9	C18:3 n6	-	-	0.15	0.05
10	C18:3 n3	3.41	10.35	10.59	8.12	10	C18:3 n3	16.98	19.68	23.17	19.94
11	C20:1	0.2	-	-	0.07	11	C20:0	-	-	0.92	0.31
12	C20:2	0.09	-	-	0.03	12	C22:0	-	-	0.34	0.11
13	C24:0	-	-	-	-	13	C24:0	-	-	0.82	0.27
	Total	99.99	100	100.01	100.00		**Total**	100	99.99	100	100.00

Physicochemical Properties of Hom Thong Banana Cellulose

a) *Fourier-transform infrared spectroscopy (FT-IR)*

The intermolecular chemistry of banana peel cellulose was characterized by using the FT-IR technique (Fig. 1 (A)). Because of the -OH groups in the hydrophilic components, the FT-IR spectra showed a large absorption peak ranging of 3,500-3,000 cm^{-1}, which was assigned to intramolecular hydrogen bonding of hydroxyl groups in cellulose. The absorption peak at 2,884.11 cm^{-1} was caused by the aliphatic -CH stretching vibration in cellulose and also hemicellulose. The C=O bonds of aldehydes or carboxylic stretching of hemicelluloses were suggested by a band in the spectra of banana peel cellulose at 1,647.70 cm^{-1}. Due to the elimination of hemicellulose by chemical treatment, the absorption peak of the ester group

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around 1730 cm-1 was not detected in commercial celluloses (HEC, HMC, and MHC). The C-O-C cellulose bond was seen in the band at 1,020.06 cm-1, indicating a significant cellulose concentration (Pelissari et al., 2017). As shown in Fig. 1 (B), the hydroxyl modification of commercial celluloses resulted in increasing the absorption intensity of the methylene group ataround 2874-2891 cm^{-1}, leading to the decreasing intensity of their H-bonding interaction at 3,500-3,000 cm^{-1}.

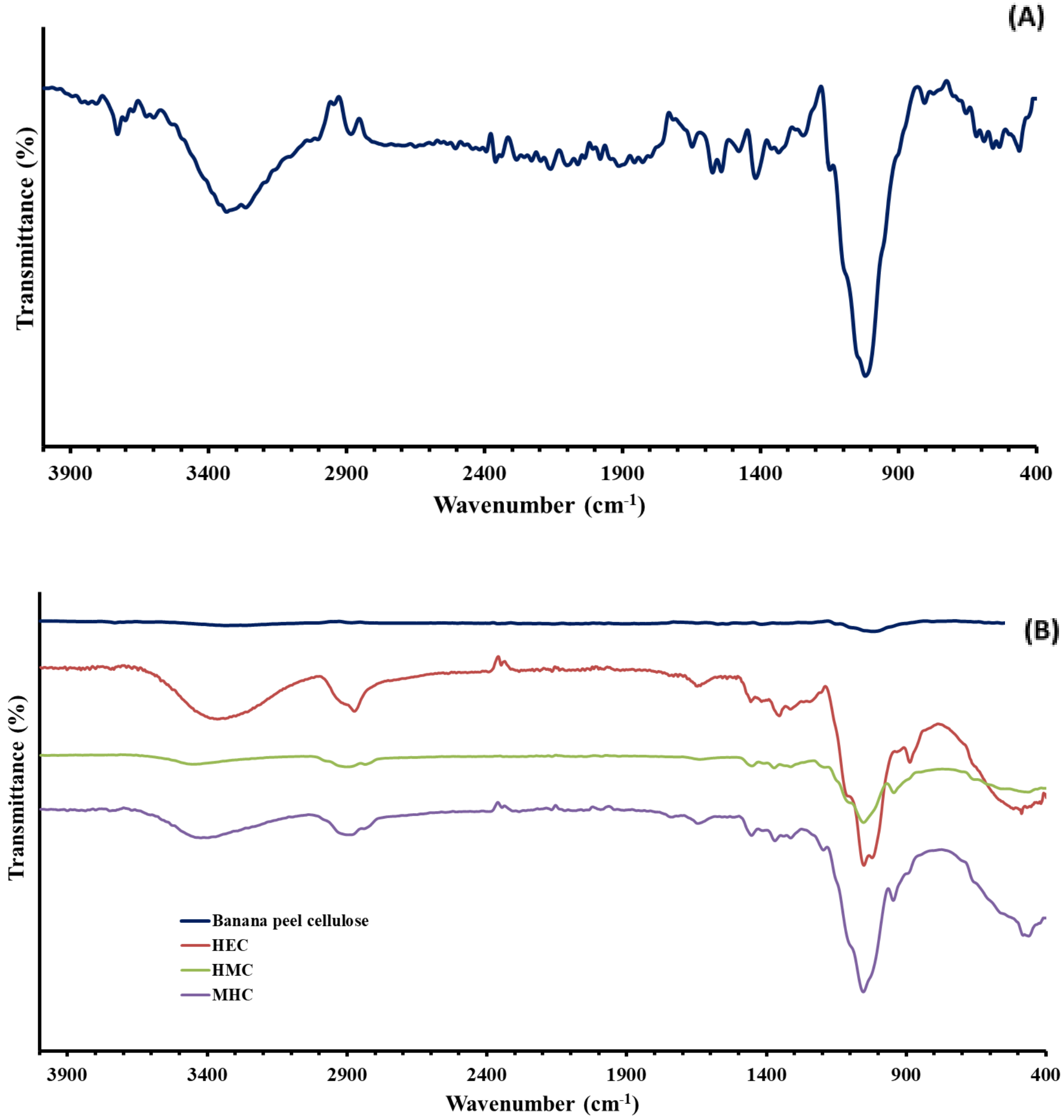

Figure 1. FTIR spectroscopy analyses of Hom Thong Banana Cellulose (A) and HEC, HMC, MHC standards (B)

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b) Differential scanning calorimetry (DSC)

Hom Thong banana cellulose was thermally analyzed by the DSC technique. As shown in Fig. 2, the result suggested that the water was evaporated around 90-130 °C with an endothermic reaction (19.838 J/g). Hemicellulose possibly degraded in the range of 170-190 °C (125.835 J/g), due to having an amorphous structure from the random structural arrangement of various polysaccharides (galactose, glucose, mannose) than those commercial celluloses (HEC, MHC, and HMC) that were degraded in range of 202-210 °C. Furthermore, cellulose would be depolymerized and then destroyed by exothermic reaction at a temperature ranging of 320-350 °C (31.157 J/g) because it might be interacted with lignin, resulting in a highly organized structure (Pelissari et al., 2014, Pelissari et al., 2017). Moreover, degradation of lignin with amorphous cross-linked structure would have occurred above
350 °C.

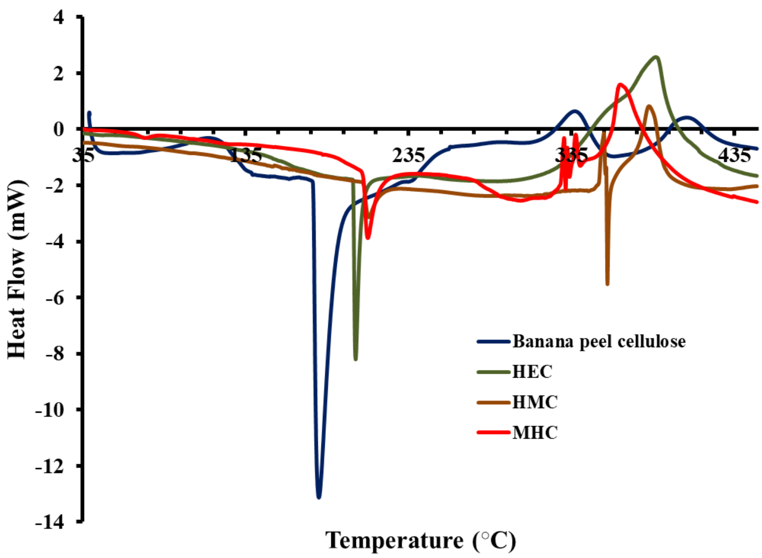

Figure 2. DSC thermograms of the Hom Thong Banana Cellulose and HEC, HMC, MHC standards

CONCLUSION

This preliminary study investigated the possibility of Hom Thong banana peel waste as an alternative cellulose source for food and cosmetic applications due to its low cost and availability. The chemical composition of fatty acid can be measured by GC-MS depending on the maturity and species of banana peel source. When cellulose extracted from Hom Thong banana peels was compared to cellulose standards using FT-IR and DSC techniques, the results exhibited varied functional groups as well as different physicochemical microstructures. Screening characterization of the obtained cellulose indicates the natural complex structure of cellulose that has the potential properties for food and cosmetic applications. However, the optimized condition of cellulose extraction, bleaching process, purification, and also mechanical properties would be further studied.

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