Original Article

EXTRACTION, CHARACTERISATION, BIOACTIVITY, AND APPLICATION OF RAMBUTAN (*Nephelium lappaceum* L)

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Abstract

In this study, parts consisting of spines, rind, seed coat and seed were sundried. The rind, seed coat and seed were powdered and subjected to ethanol extraction and subjected for characterization using Thin Layer Chromatography (TLC) and Fourier Transform Infrared Spectroscopy (FTIR). Anti-bacterial and Anti-fungal activity tests by well diffusion method in agar plates were performed. The powdered samples and spines were subjected to fiber extraction and subjected for FTIR analysis, and lignocellulosic content. Fibers from spines and powdered samples were used for removal of crystal violet and chromium in adsorption study. Rind has antimicrobial properties against *S. aureus*, *E. coli*, and *C. albicans*. Seed has antibacterial property against *E. coli*. Fibers of spine, rind, seed coating and seed all showed highest content of lignin and showed some adsorbent property.

Keywords: Rambutan, antibacterial activity, antifungal activity, adsorbent.

Introduction

Rambutan fruit (*Nephelium lappaceum* L) is a source of natural fiber[1]. The tree that bears the fruit is of medium-sized type with the same name. Rambutan fruit is in the soapberry family, Sapindaceae[1]. Rambutan are found in various tropical countries such as in Southeast Asia where it is native, especially in Indonesia and Malaysia where the fruit is commonly eaten raw[2]. The fruit has an ovoid shape with an outer rind of around 3mm thick that is

greenish when young and can be yellowish to reddish in colour when ripe[3]. The rind has portruding, pliable spinterns or spines of the same colour as the rind which is what give the name 'Rambutan' to the fruit, as it means 'hair' with the suffic '-an'. The length of the spines can vary from 0.5cm to 2.0cm[4]. The flesh or pulp inside is called the aryl and is edible. It is whitish transluscent, mainly consists of water and has a sweet to sour taste[3]. In the core of the aryl is the seed that is also surrounded by a thin and woody layer of seed coating that separates the seed from the aryl[3]. When rambutan is being eaten raw, only the aryl is consumed, leaving the rind, spines, and seed with the seed coating as wastes. Extraction of bioactive compounds was discussed by Mistriyani et al.[5] in which rambutan rind was washed, cut into small pieces and dried under the sun before extracted with methanol using maceration procedure. Vacuum rotary evaporator was used to filter and evaporate the macerate before mixing with warm distilled water and fractionated with petroleum ether. The residue was fractionated for the second time with chloroform and ethyl acetate to produce various fractionated extracts[5].

Rambutan has been reported to have various bioactivity. Inhibition zones were observed by extract of rambutan rind against *Salmonella typhimurium, Micrococcus luteus, Bacillus sp.,* and *Staphylococcus aureus*[6]. Another study used dilution method to study the antibacterial and antifungal activity of rambutan rind extract[7]. It was found that rambutan rind has inhibitory activity at various concentrations and incubation durations against *Staphylococcus aureus, Listeria monocytogenes, Escherichia coli, Salmonella enteritidis, Vibrio anguillarum, Vibrio campbellii, Vibrio parahaemolyticus* and *Pseudomonas aeruginosa*, as well as antifungal activity against *Candida albicans*[7].Similar pattern of results were seen in a study by Nethaji et al.[8] that showed antimicrobial activity of rambutan rind against *Escherichia coli, Klebsiella pneumoniae, Pseudomonas vulgaris,* and *Aspergillus fumigatus*[8].

Fibers can be categorized into natural and man-made fibers, and both have found their uses in various industries and fields such as automotive, medical, textile, and construction. Man-made fibers are produced through chemical manufacturing process, while natural fibers can be found developing and existing naturally in nature such as from plants, animals and mineral sources[9]. Plant fibers consist of polysaccharides mainly made up of cellulose and can be further categorized based on the parts of the plants they are found on such as bast, bark, peel, seed, leaf and fruit [10-11]. Examples of seed fibers include cotton, kapok and coir while example of bast fibers are flax, hemp and jute[12]. The cellulose that is present in these plant fibers can exist in its pure form, but is commonly associated by lignins, hemicelluloses and other soluble compounds in smaller amount[13]. These fibers are used in various purposes, one such is heavy metal removal. The purpose of adsorption studies is generally to remove pollutants which cannot be biodegraded easily[14]. The use of agricultural wastes such as biomass, clay, solid wastes for environmental remediation like the removal of dyes and heavy metal are highly efficient, renewable, and low-cost[15-17]. Fruit shells such as coconut has dynamic functional groups of hydroxyl (OH) and carboxyl (COOH) in their pectin, cellulose, and hemicellulose which can bind to toxic matters and elements such as cadmium, plumbum and arsenic. Fruit shell-based adsorbents have been studied for removal of copper from galvanic wastewater[18]. Torgbo et al. [19] reported that cellulose fibers from the rambutan peel assessed by the electrothermal pretreatment which had various industrial applications as it is eco-friendly, improves the efficiency and energy consumption in processing of fibers. Hence, in this study various parts of the rambutan have been subjected for extraction, characterized and it underwent into bioactivity studies where the fibers extracted were subjected for adsorption studies for heavy metal removal.

Materials and Method

Materials used

Ethanol, sodium hydroxide (NaOH), chloroform, methanol, acetone, sodium hypochlorite (NaOCl) and sulfuric acid were bought from Bendason. Iodine pellets, 2,2-diphenyl-1-picrylhydrazyl (DPPH) and barium chloride were from R&M Chemicals. Nutrient agar powder, nutrient broth powder and Sabouraud Dextrose Agar (SDA) powder were from HiMEDIA, crystal violet dye and potassium dichromate were from HmbG Chemicals. The chemicals and solvents used in this study were all analytical grade.

Rambutan was obtained from local market in Bandar Saujana Putra, Selangor, Malaysia. The rinds were cut open and the aryls were removed and were rinsed to remove juice residue and other contaminants. It was dried under the sun for 5 days. Rambutan spines were separated from the rind, residual aryls were removed from the seed coatings, and the seed coatings were separated from the seeds. The dried rinds, seed coatings and seeds were grounded in blender to produce powdered samples.

Extraction

10g of powdered samples were mixed with 100 ml of ethanol and kept in shaker incubator, in room temperature at 100rpm overnight. The residue was removed using filter paper and the filtrate was concentrated by leaving in fume hood overnight[6].

Thin Layer Chromatography & Bioautography for Antioxidant

Ethanol extracted samples were loaded onto TLC plates. TLC was run in solvent chambers of chloroform, ethanol, distilled water, and ethanol-distilled water solution (1:1) as the mobile phases. Solvent front was marked on the resulting plates and left to dry. Results were observed by exposure to iodine, and antioxidant bioautography was observed by spraying the plates with DPPH20. Retention factor (RF) was calculated according to the following formula:

Retention factor (RF) = Distance travelled by sample ÷ Distance travelled by solvent

Bioactivity studies

Antibacterial Activity

The procedure was started with ethanol extracted samples (rind, seed coat and seed) were dissolved into water to have different concentrations (100%, 80%, 60%, 40%, and 20%) (µl/µl). Nutrient agar plates were then swabbed all over with *Staphylococcus aureus*. Six wells were made in the plates and samples were loaded according with samples. The cultured plates were incubated at 37°C for 24 hours. The zone of inhibition was observed and measured. The same procedure was repeated with *Escherichia coli* [21-22].

Antifungal Activity

Ethanol extracted samples were prepared in concentrations as mentioned above. Sabouraud Dextrose Agar (SDA) plates were swabbed with *Candida albicans*. Six wells were made in the plates using puncher, and samples were loaded accordingly. The cultured plates were incubated at 37°C for 24 hours. The zone of inhibition was observed and measured[23-24].

Fiber Extraction

Water-insoluble polysaccharides were extracted from the raw powdered samples and spines according to a modification of Kouadri & Satha[25] method through the following steps. Deproteinization was done by mixing the sample with 1M NaOH (1:30, g/ml) for 6hours at 70 °C. The insoluble part was collected by centrifugation at 10,000 rpm for 20 minutes, and washed with distilled water until it reaches neutral pH. The sample was dried in hot air oven at 60 °C for 24 hours to produce light brown powder. Next was the lipid removal by mixing the sample with chloroform-methanol (2:1) solution at ratio of 1:20, g/ml for 4 hours. The insoluble part was collected by centrifugation at 10 000 rpm for 20 minutes, and washed with acetone three times, before drying in oven at 60 °C for 24 hours. Following that was bleaching by mixing with 2% NaOCl (1:30, g/ml) for an hour at 90°C. The insoluble part was collected using filter paper and washed with distilled water until neutral pH. Then the sample was dried at 60 °C for 24 hours. The last step was cellulose nanofibers extraction by mixing the sample with 40%

sulfuric acid in ratio of 20:1 (mg/ml) for an hour. Then the sample was diluted in distilled water to stop the acid hydrolysis and centrifuged at 10 000 rpm, at 10°C for 20 minutes to separate the insoluble part. Next was washing with distilled water until neutral pH and drying at 60°C for 24 hours. Then, the sample was resuspended in distilled water and treated by sonication at 20kHz for 10 minutes, before filtering.

Characterization of fiber

The extracted fiber was characterized using Fourier-Transform Infrared Spectroscopy (Shimadzu, IRTRACER 100, Kyoto, Japan). The extracted fiber was analyzed for cellulose, hemicellulose, and lignin content which was done by the method of Mansor et al. [26].

Heavy metal removal

Adsorbate preparation was prepared by preparing chromium in distilled water as stock solution. Absorbance was measured using UV-Vis spectrophotometer at 370nm to obtain the standard curve. Following that, adsorbate optimization was performed by mixing 5g/L samples with chromium solution and left for 2hours. The solution was then centrifuged at 10,000rpm for 15minutes. The absorbance of supernatant was measured using UV-Vis spectrophotometer at 370nm. The steps were repeated for all chromium concentrations[27]. The final concentration of chromium was calibrated from the standard curve and the removal percentage of adsorbate was calculated by the following formula:

$$\text{Removal}\,\% = \frac{\text{Initial conc.} - \text{Final conc.}}{\text{Initial conc.}} \times 100$$

Results and discussion

Ethanol Extracts

10g of powdered rind yield out 0.83 g of extract, 6 g of powdered seed coat yield out 2.04 g of extract, and 10 g of powdered seed yield out 1.13g of extract. Orozco et al. [28] suggested that the amount of extracted bioactive compounds can be optimized by performing three successive extractions at 60 °C for 1 hour each in 55% ethanol.

Fourier Transform Infra-Red (FTIR) of Ethanol Extracts

The FTIR spectroscopic analysis revealed presence of various functional groups in the bioactive compounds of rambutan wastes extracts. Rambutan rind extract produced wavenumbers of 3339.03cm^{-1} which corresponds to a normal polymeric OH stretch of alcohols and phenols. At 1635cm^{-1}, the wavenumber corresponds to alkenyl C=C stretch (Figure 1). 1254.46cm^{-1} corresponds to aromatic ethers with aryl-O stretch. 715.15cm^{-1} corresponds to an OH out-of-plane bend of an alcohol. 496.07cm^{-1} corresponds for S-S stretch for polysulfides. The FTIR spectra of rambutan seed coating ethanol extract (Figure 2) consist of some similar wavenumbers as rind extracts with broad band at 3272.2 cm^{-1} due to the hydroxyl group (OH)- stretching vibration and at 1639.44 cm^{-1} is due to a C=C stretch. At 1460.51 cm^{-1} is due to C-H asymmetrical bend. At 1418.32cm^{-1}, the wavenumber corresponds to carbonate ion. The peak at 1057.68cm^{-1} indicates the presence of aliphatic amines. Rambutan seed extract produced wavenumbers of 3325.49 cm^{-1} which corresponds to a normal polymeric OH stretch of alcohols and phenols. At 2923.27 cm^{-1}, and 2853.28 cm^{-1} the wavenumbers corresponds to methylene C-H (Figure 3). 1744.23 cm^{-1} corresponds to carbonyl compound of either an ester or alkyl carbonate. 1638.61cm^{-1} corresponds to simple hetero-oxy compounds of organic nitrates. At 1465.66 cm^{-1} is due to C-H bond. The peak at 1056.64 cm^{-1} indicates the presence of aliphatic amines.

Figure 1. FTIR spectra of rambutan rind extract.

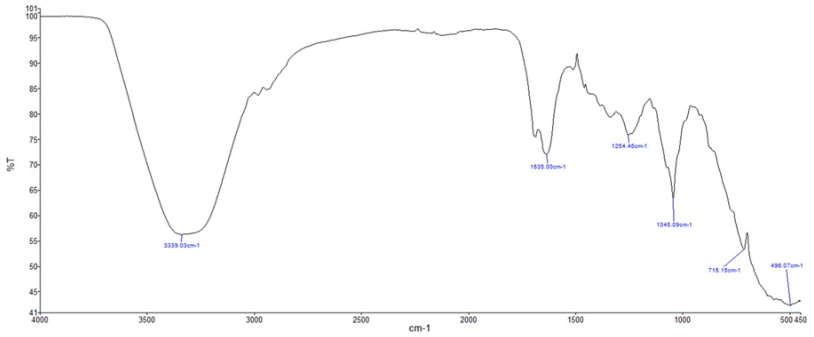


Figure 2. FTIR spectra of rambutan seed coat extract.

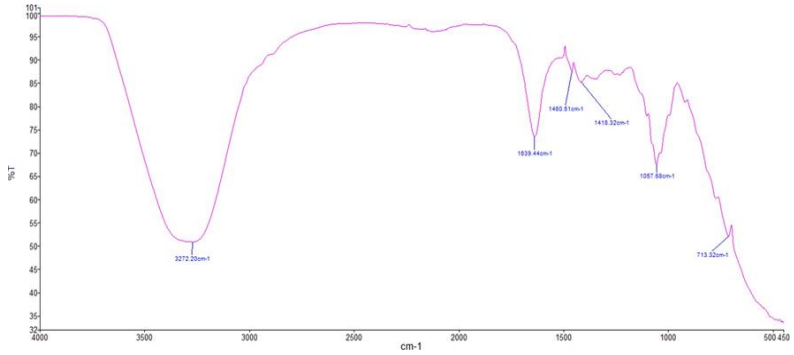
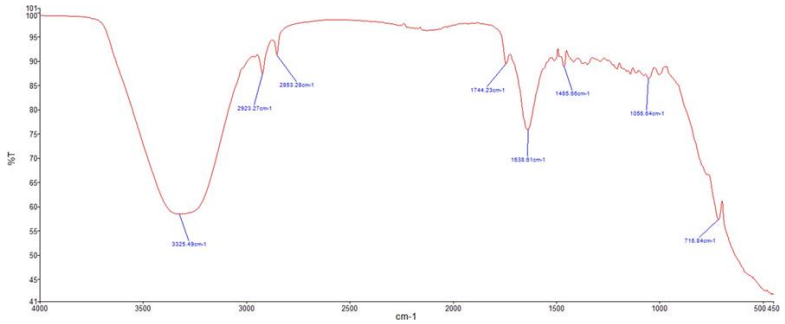


Figure 3. FTIR spectra of rambutan seed extract.



Thin Layer Chromatography & Bio-autography for Antioxidant

TLC was performed for rind, seed coat and seed using different solvent systems like chloroform, ethanol, distilled water and ethanol- distilled water which was exposed to iodine and then antioxidant activity was checked using DPPH spray (Figure 4, Figure 5) and the obtained R_f values are tabulated (Table 1 and 2). Bag et al.[29] reported that coriander seed oil showed the presence of four antibacterial where the R_f: 0.20, 0.35, 0.61, 0.80 and three antioxidant where the R_f- 0.35, 0.58, 0.80 constituents. Ahamed et al.[30] reported TLC studies of the ethanol extract of *T.roxburghianum* Hexane: Ethylacetate: Acetic Acid (4:4:2) was used as solvent system and 4 spots were visible and the R_f values were 0.50, 0.62, 0.87, 0.95 respectively. Asante et al. [31] reported that extracts from *V. unguiculata* which records a total of seven bands with five unique bands with the following R_f values: 0.06, 0.18, 0.22, 0.31 and 0.46 indicates flavonoid.

Figure 4. Thin Layer Chromatography & Bio-autography for Antioxidant – exposed to Iodine A) Chloroform as solvent B) ethanol as solvent C) distilled water as solvent D) ethanol- distilled water as solvent. (i) Rind, (ii) Seed Coat, (iii) Seed

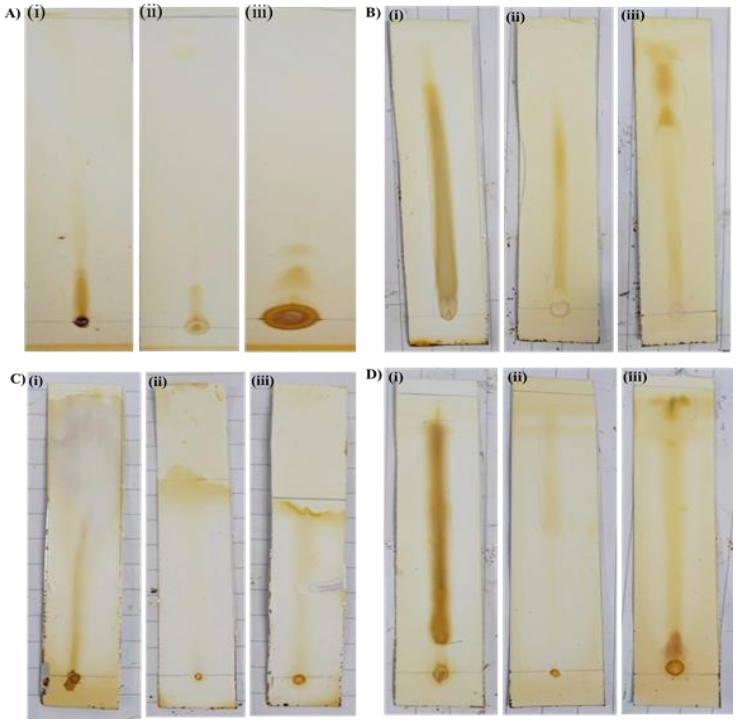


Figure 5. Thin Layer Chromatography & Bio-autography for Antioxidant – observed using DPPH spray A) Chloroform as solvent B) ethanol as solvent C) distilled water as solvent D) ethanol- distilled water as solvent. (i) Rind, (ii) Seed Coat, (iii) Seed

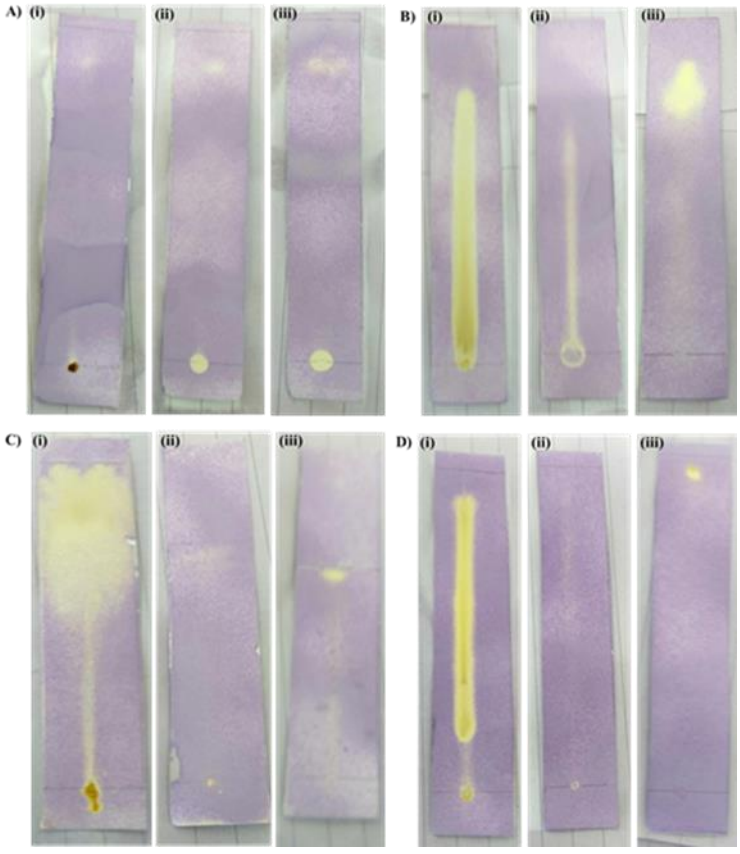


Table 1. Thin Layer Chromatography exposed to iodine

Samples	Mobile Phase			
	Chloroform solvent	**Ethanol solvent**	**distilled water solvent**	**Ethanol- distilled water solvent**
(i) Rind	0.14	0.76	0.58	0.88
(ii) Seed Coat	0.11	0.70	0.70	0.92 0.88
(iii) Seed	0.16	0.96	0.65	0.98 0.87

Table 2. Thin Layer Chromatography - bioautography for Antioxidant activity

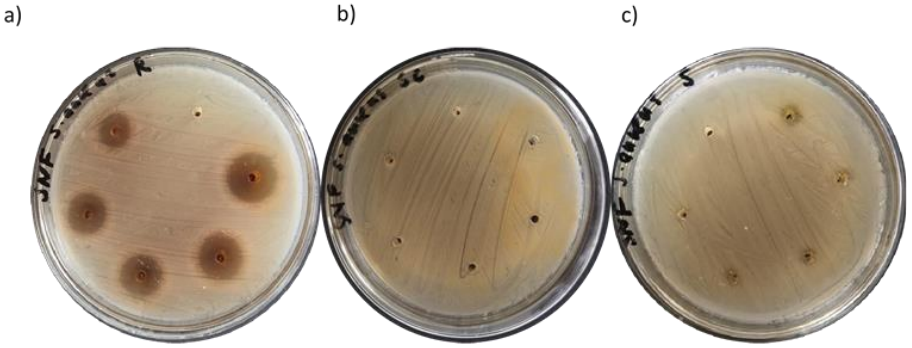
Samples	Mobile Phase			
	Chloroform solvent	**Ethanol solvent**	**distilled water solvent**	**Ethanol- distilled water solvent**
(i) Rind	0.98	0.76	0.99	0.88
(ii) Seed Coat	0.97	0.70	0.73	0.98
(iii) Seed	0.98	0.96	0.65 0.64	0.98

Bioactivity studies

Antibacterial Activity

Results of well diffusion test against *Staphylococcus aureus* showed formation of inhibition zones by rambutan rind at 0.6 cm, 1.0 cm, 1.7 cm, 1.8 cm, and 2.0 cm with increasing concentration of extracts, while seed coating and seed did not produce any inhibition zone (Figure 6). Similarly, the rind also showed antibacterial activity against *Escherichia coli* by the formation of inhibition zones that increases with increasing concentration of the extract (results not shown here). Antibacterial activity of rambutan rind against *S. aureus* was also observed in other studies such as by Sukatta et al.[6], however this study showed no antibacterial activity against *E. coli*, similar to a study by Sekar et al.[32]. The study by Phuong et al.[7] however, showed antibacterial activity against both of the bacteria. This difference may be due to the different technique of extraction which results in different content and amount of bioactive compounds in the extract. Seed extract also showed minimal antibacterial activity at the higher concentration against *S.aureus* (figure 6c) and *E. coli* (result not shown here).

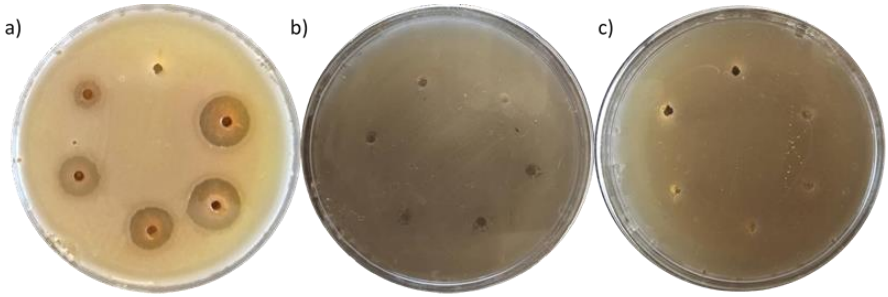
Figure 6. Antibacterial activity of rambutan a) rind, b) seed coat and c) seed against *S. aureus*.



Antifungal Activity

Results of well diffusion test against *Candida albicans* showed formation of inhibition zones by rambutan rind at 0.8cm, 1.2cm, 1.3cm, 1.5cm and 1.5cm with increasing concentration of extracts, while seed coat and seed did not produce any inhibition zone (Figure 7). This result is aligned with the result from a study by Phuong et al.[7].

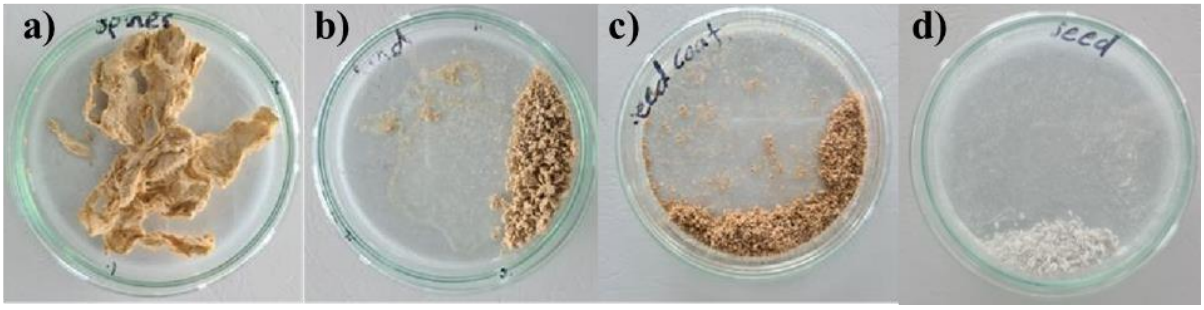
Figure 7. Antifungal activity of rambutan a) rind, b) seed coat and c) seed against *C. albicans*



Fiber extraction

The extraction to get the purified fibers from the spine, rind, seed coating and yielded out between 10-25% of fiber. More amount of raw samples or improvement in the methodology is needed to produce sufficient amount of processed fiber for further testing and assays. Another modification of fiber extraction by Kouadri & Satha[10] suggested starting the procedure with lipid removal and followed by protein extraction to have better yield. This method also allows for better estimation of lipid and protein contents in the sample. 10g of spine, 10g of powdered rind, 6g of seed coating and 10g of seed yielded out around 1.0-1.5g of processed fibers that were lighter in colour (Figure 8).

Figure 8. Extracted fibers of a)rambutan spine, b)rind, c)seed coat, and d)seed.



Fiber Characterization

Fourier Transform Infra-Red of Processed Fiber

Rambutan spine fiber produced sharp peaks at 2916.23 cm^{-1} and 2849.62 cm^{-1} which corresponds to C≡C which is present in wax (Figure 9)[33]. The peak signals at 1727.74 cm^{-1} and 1540.39 cm^{-1} corresponds to C=O stretching of hemicelluloses and C=C symmetrical stretching aromatic ring in lignin[34]. At 1472.21 cm^{-1} and 1431.30 cm^{-1} the wavenumbers indicate deformation of lignin CH_2 and CH_3. 1369.83 cm^{-1} indicates nitrate ion, while 1316.03 cm^{-1} indicates dialkyl/aryl sulfones[35]. 1217.29cm^{-1} and 1033.35cm^{-1} correspond to C-O stretching common for hemicellulose and cellulose [36].

For rambutan rind fiber, the FTIR analysis showed wavenumber of 3313.55cm^{-1} corresponding to a normal polymeric OH stretch (Figure 10). 2917.08 cm^{-1}, and 2849.67 cm^{-1} correspond to C-H and CH_2 stretching that are abundant in polysaccharides[33]. At 1738 cm^{-1} is the C-O if unconjugated ketones, carbonyls, carboxylic acids indicating lignin oxidation during extraction[34]. 1217.15 cm^{-1} indicates aromatic phosphates with P-O-C stretch. 1032.26cm^{-1} is corresponding to C-O stretching.

As for the rambutan seed coat fiber, in Figure 11, the FTIR spectra showed peak at 2970.70 cm^{-1} corresponding to C-H and CH_2 stretching common in polysaccharide[35]. At 1740.20 cm^{-1} is corresponding to C=O stretching of unconjugated hemicellulose[34]. 1368.36 cm^{-1} indicates aliphatic nitro compound. 1217.02 cm^{-1} indicates aromatic phosphates with P-O-C stretch[33]. 1038.03 cm^{-1} indicates C-O stretching common in cellulose and lignin.

FTIR analysis of rambutan seed fiber (Figure 12) showed wavenumber of 2955.46 cm^{-1}, 2915.95 cm^{-1} and 2849.41 cm^{-1} corresponding to stretching of CH, CH_2 and CH_3 common in cellulose and hemicellulose[35]. At 1703.78 cm^{-1}, the peak corresponds to C=O stretching of unconjugated hemicellulose[33]. 1584.14 cm^{-1} and 1539.06 cm^{-1} correspond to C=C stretching vibration of aromatic ring in lignin[34]. 1464 cm^{-1} and 1430.49 cm^{-1} correspond to deformation of lignin CH_2 and CH_3. Wavenumbers of 1377.68 cm^{-1}, 1331.72 cm^{-1} and 1315.88 cm^{-1} correspond to OH bend of primary, secondary or tertiary alcohol. 1107.45 cm^{-1} indicates presence of C-O stretch in secondary alcohol, while 1032.6 cm^{-1} indicates C-O stretch in primary alcohol. 942.28 cm^{-1} and 909.56 cm^{-1} indicate vinyl C-H out-of-plane bend of alkene as well as interaction between the sugar units of hemicellulose and cellulose in the ß-1,4 glycosidic bond[36]. 716.85 cm^{-1} corresponds to skeletal vibration of C-C. 667.31 cm^{-1} and 609.25 cm^{-1} correspond to alkyne C-H bend.

Figure 9. FTIR spectra of rambutan spine fiber

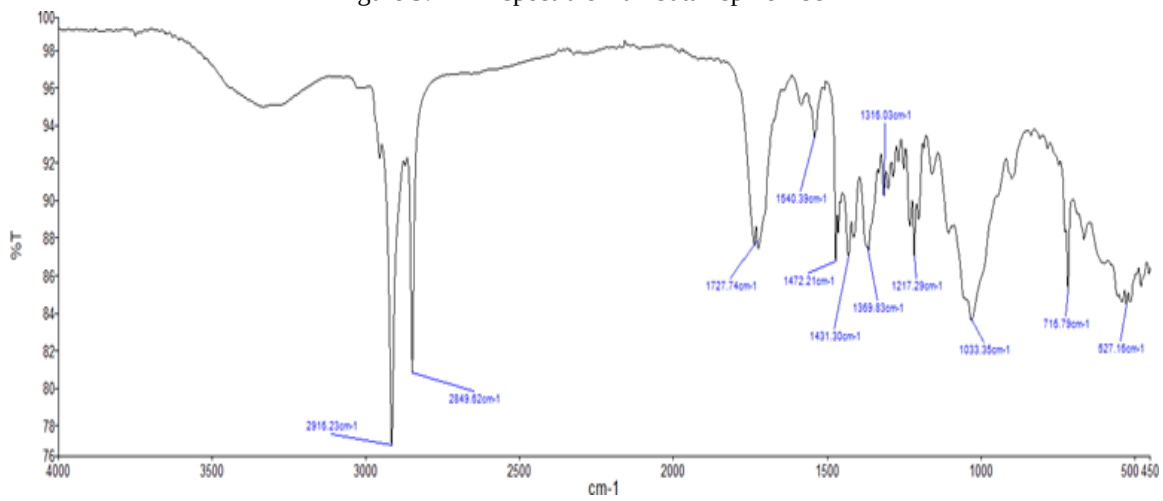


Figure 10. FTIR spectra of rambutan rind fiber

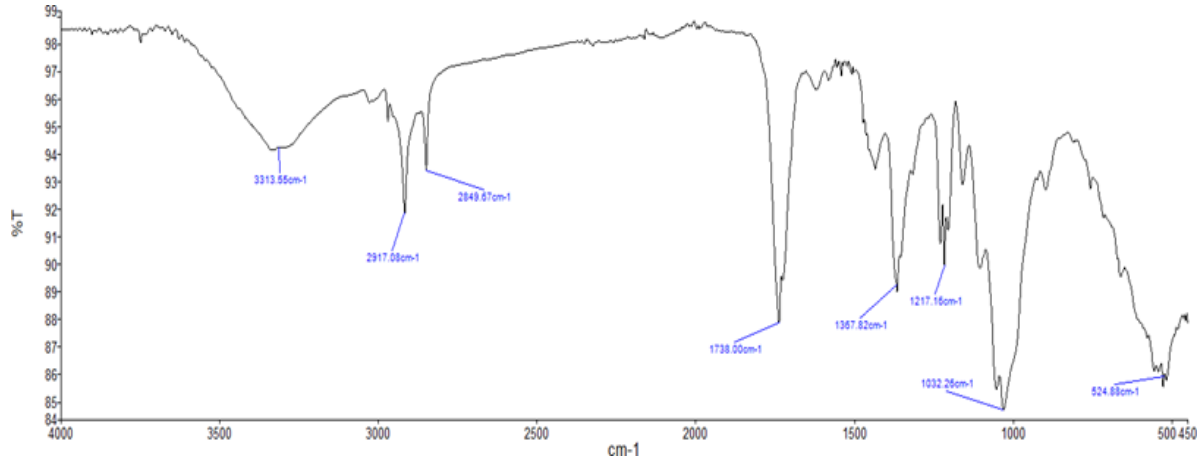


Figure 11. FTIR spectra of rambutan seed coat fiber

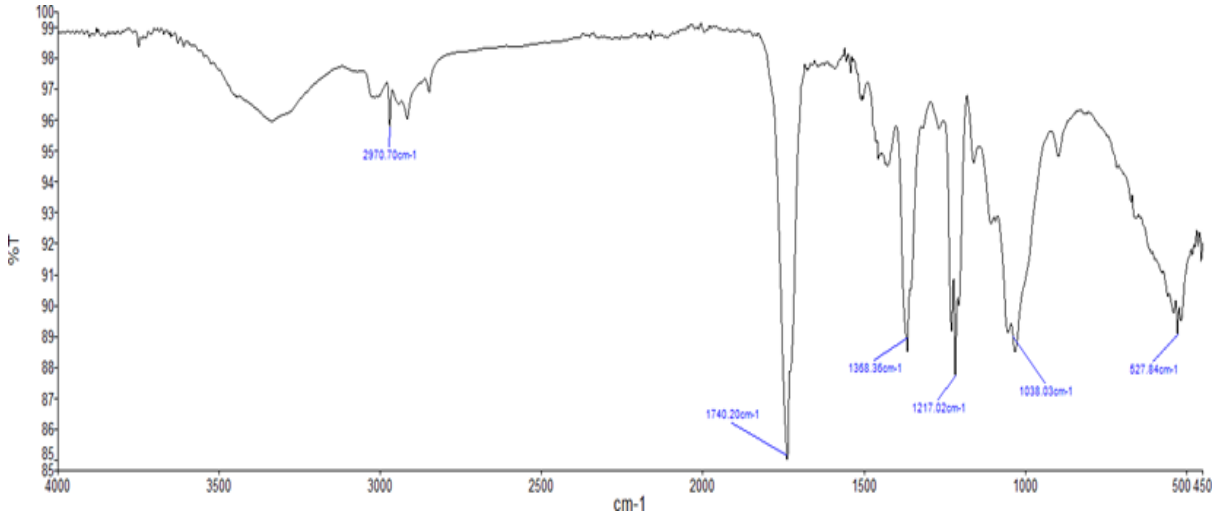
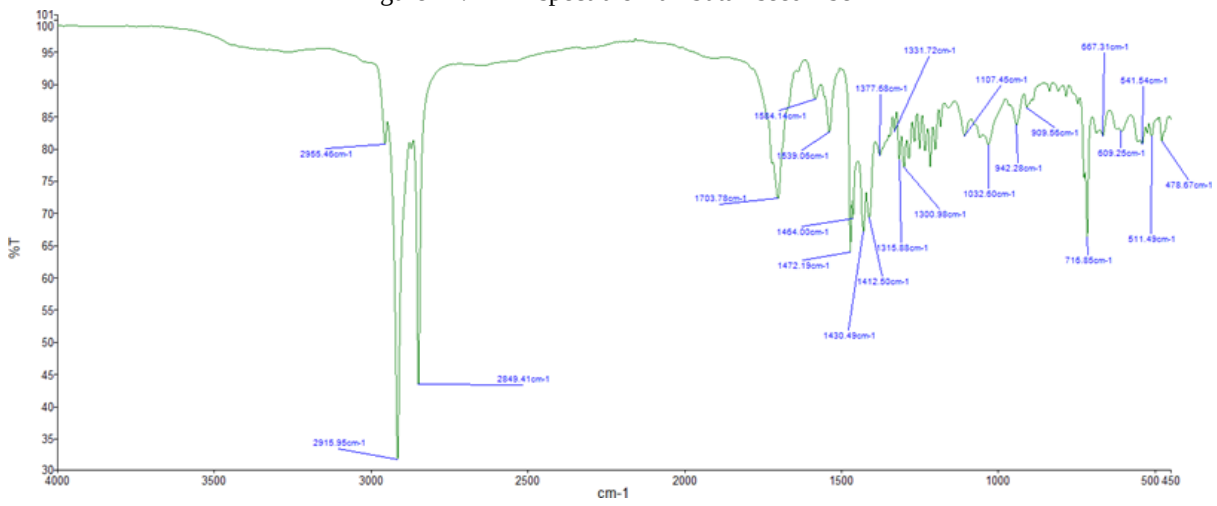


Figure 12. FTIR spectra of rambutan seed fiber



Determination of cellulose, hemicellulose and lignin content

The cellulose, hemicellulose, and lignin content of rambutan rind fiber were 14 %, 28 %, and 56% respectively (Table 3) where Oliveira, et al. [37] found ~22%, ~14%, and 37% in rambutan peel fiber. Lignin percentage was higher in all the samples (Table 3). The content of extractive, hemicellulose, cellulose and lignin in the rambutan spine, rind, seed coating, and seed were quantified based on percentage of weight loss[26]. Extractive mainly consists of cell wall chemicals containing fatty acids, fatty alcohols, phenols steroids, terpenes, fats, resin acid, waxes and other organic compounds which are responsible for colour, smell and durability of the biomass[38]. Hemicellulose consists of various type of monosaccharides and their derivatives including glucose, galactose, mannose, xylose, arabinose, uronic acids, and glucuronic that are connected in a highly branched network[39]. It supported the structural integrity of a plant. Cellulose is the main structural component in the plant cell and can be categorized into crystalline and non-crystalline or amorphous, according to the presence of rigid microfibrils formed by strong hydrogen bonds[39]. The different types also differ by their ability to interact with water, microbes and other surrounding molecules[38]. Lignin is a highly polymerized molecule that is more amorphous compared to cellulose and hemicellulose. The content is higher in cell walls of older and more woody plants such as what is observed in the rambutan samples, as it provides rigidity and strength, as well as physicochemical barrier against microbial attack[39].

Table 3. Amount of extractives, hemicellulose, lignin and cellulose in 1g sample of rambutan spine, rind, seed coating and seed fibers.

Sample	Extractive (g)	Hemicellulose (g)	Lignin (g)	Cellulose (g)
Spine	**0.07**	**0.26**	**0.55**	**0.12**
Rind	**0.02**	**0.28**	**0.56**	**0.14**
Seed coating	**0.07**	**0.15**	**0.53**	**0.25**
Seed	**0.2**	**0.1**	**0.36**	**0.33**

Chromium metal adsorption studies

Seed coat fibre showed higher removal of chromium from the solution than the other fibers extracted in this study and it showed removal percentage of 58 % for 2 ppm chromium with the interaction period of 2 hours (Results are not shown here). The removal is comparatively very less than the earlier reports.

Conclusion

In this study, it was found that rind extract is having good antibacterial and antifungal activity. Most extracts do possess antioxidant activity which was evidenced by TLC bioautography analysis. Fibers extracted from seed coat showed a good adsorbent property than the other fibers.

Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

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References

1. Hernández-Hernández C, Aguilar CN, Rodríguez-Herrera R, Flores-Gallegos AC, Morlett-Chávez J, Govea-Salas M, Ascacio-Valdés JA. Rambutan (*Nephelium lappaceum* L.): Nutritional and functional properties. Trends in food science & technology. 2019;85:201-10.

2. Kumoro AC, Alhanif M, Wardhani DH. A critical review on tropical fruits seeds as prospective sources of nutritional and bioactive compounds for functional foods development: a case of Indonesian exotic fruits. International journal of food science. 2020;2020.

3. Windarsih G, Efendi M. Morphological characteristics of flower and fruit in several rambutan (Nephelium lappaceum) cultivars in Serang City, Banten, Indonesia. Biodiversitas Journal of Biological Diversity. 2019;20(5).

4. Shahrajabian MH, Sun W, Khoshkharam M, Cheng Q. Rambutan, a tropical plant with ethno-pharmaceutical properties. Agrociencia. 2020;54(1):121-8.

5. Mistriyani, Riyanto S, Rohman A. Antioxidant activities of Rambutan (Nephelium lappaceum L) peel in vitro. Food research. 2017.

6. Sukatta U, Rugthaworn P, Khanoonkon N, Anongjanya P, Kongsin K, Sukyai P, Harnkarnsujarit N, Sothornvit R, Chollakup R. Rambutan (Nephelium lappaceum) peel extract: Antimicrobial and antioxidant activities and its application as a bioactive compound in whey protein isolate film. Songklanakarin Journal of Science & Technology. 2021;43(1).

7. Phuong NN, Le TT, Van Camp J, Raes K. Evaluation of antimicrobial activity of rambutan (Nephelium lappaceum L.) peel extracts. International journal of food microbiology. 2020;321:108539.

8. Nethaji R, Thooyavan G, Mullai Nilla K, Ashok K. Phytochemical profiling, antioxidant and antimicrobial activity of methanol extract in rambutan fruit (Nephelium lappacium) epicarp against the human pathogens. International Journal of Current Innovation Research. 2015;1(9):201-6.

9. Ryszard M K, Maria MT, Malgorzata M, Jorge BB. Future of natural fibers, their coexistence and competition with man-made fibers in 21st century. Molecular Crystals and Liquid Crystals. 2012;556(1):200-22

10. Kozlowski R, Mackiewicz-Talarczyk M, editors. Handbook of natural Fibers: volume 1: types, properties and factors affecting breeding and cultivation. Woodhead Publishing; 2020.

11. Samrot AV, Michael EN, Anand DA, Mercy JL, Sabesan GS, Mohanty BK, Visvanathan S, Saigeetha S. The utilization of Garcinia mangostana fibers for the removal of crystal violet dye. Materials Today: Proceedings. 2022.

12. Mather RR, Wardman RH. The chemistry of textile Fibers. Royal Society of Chemistry; 2015.

13. Ramawat KG, Ahuja MR, editors. Fiber plants: biology, biotechnology and applications. Springer; 2016.

14. De Gisi S, Lofrano G, Grassi M, Notarnicola M. Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: a review. Sustainable Materials and Technologies. 2016;9:10-40.

15. Samrot AV, Purohit K, Saigeetha S, Shobana N, Dhas TS, Cypriyana PJ. *Citrus sinensis* cellulose Fibers incorporated with SPIONs for effective removal of crystal violet dye. Biocatalysis and Agricultural Biotechnology. 2022;39:102211.

16. Samrot AV, Ngaakudzwe KT, Rajalakshmi D, Prakash P, Suresh Kumar S, Chandramohan M, Alex Anand D, Lilly Mercy J, Simon Y, Saigeetha S. Waste-Derived Cellulosic Fibers and Their Applications. Advances in Materials Science and Engineering. ;2022.

17. Rafatullah M, Sulaiman O, Hashim R, Ahmad A. Adsorption of methylene blue on low-cost adsorbents: a review. Journal of hazardous materials. 2010;177(1-3):70-80.

18. Younas F, Mustafa A, Farooqi ZU, Wang X, Younas S, Mohy-Ud-Din W, Ashir Hameed M, Mohsin Abrar M, Maitlo AA, Noreen S, Hussain MM. Current and emerging adsorbent technologies for wastewater treatment: trends, limitations, and environmental implications. Water. 2021;13(2):215.

19. Torgbo S, Sukyai P, Khantayanuwong S, Puangsin B, Srichola P, Sukatta U, Kamonpatana P, Beaumont M, Rosenau T. Assessment of Electrothermal Pretreatment of Rambutan (Nephelium lappaceum L.) Peels for Producing Cellulose Fibers. ACS omega. 2022 ;7(44):39975-84.

20. Samrot AV, Raji P, Selvarani JA, Angalene LA, Sruthi DP, Paulraj P, Iyappan P. A. 2019. Handbook on Phytochemical extraction, screening and its in-vitro bioactivity assays. Publisher SARAS Publications. ISBN: 978-93-86519-60-3

21. Samrot AV, Shobana N, Jenna R. Antibacterial and antioxidant activity of different staged ripened fruit of Capsicum annuum and itsgreen synthesized silver nanoparticles. BioNanoScience ,2018, 8:632–646

22. Samrot AV, Qi NX, Pachiyappan S, Saigeetha S, Shobana N, Chinni SV, Dhiva S, Rajalakshmi D. Extraction, Characterization and Applications of Latex of *Manilkara zapota*. Journal of Pharmaceutical Negative Results. 2022d :109-17.

23. Parveen S, Wani A H, Shah M A, Devi H S, Bhat M Y, & Koka J A. Preparation, characterization and antifungal activity of iron oxide nanoparticles. Microbial Pathogenesis, 2018, 115, 287–292.

24. Antony VS, Sahithya CS, Durga Sruthi P, Selvarani J, Raji P, Prakash P, Ponnaiah P, Petchi I, Pattammadath S, Keeyari S. Itraconazole coated super paramagnetic iron oxide nanoparticles for antimicrobial studies. Biointerface Res. Appl. Chem. 2020;10:6218-25.

25. Kouadri I, Satha H. Extraction and characterization of cellulose and cellulose nanofibers from Citrullus colocynthis seeds. Industrial Crops and Products. 2018;124:787-96.

26. Mansora AM, Lima JS, Anib FN, Hashima H, Hoa WS. Characteristics of cellulose, hemicellulose and lignin of MD2 pineapple biomass. Chem. Eng. 2019;72(1):79-84.

27. Henryk, K., Jaroslaw, C. and Witold, Z., 2016. Peat and coconut fiber as biofilters for chromium adsorption from contaminated wastewaters. Environmental Science and Pollution Research, 23(1), pp. 527-534.

28. Boyano-Orozco L, Gallardo-Velázquez T, Meza-Márquez OG, Osorio-Revilla G. Microencapsulation of rambutan peel extract by spray drying. Foods. 2020;9(7):899.

29. Bag A, Chattopadhyay RR. Evaluation of synergistic antibacterial and antioxidant efficacy of essential oils of spices and herbs in combination. PloS one. 2015;10(7):e0131321.

30. Ahamed T, Rahman SM, Shohael AM. Thin layer chromatographic profiling and phytochemical screening of six medicinal plants in Bangladesh. International Journal of Biosciences. 2017;11(1):131-40.

31. Asante IK, Owusu E, Essilfie MK, Kwarteng M, Amuzuah O. Phytochemical investigation and thin layer chromatography of methanolic extracts of some selected grain legumes. Journal of Pharmacognosy and Phytochemistry. 2016; 1;5(3):240.

32. Sekar M, Jaffar FN, Zahari NH, Mokhtar N, Zulkifli NA, Kamaruzaman RA, Abdullah S. Comparative evaluation of antimicrobial properties of red and yellow rambutan fruit peel extracts. Annual Research & Review in Biology. 2014:3869-74.

33. Arthanarieswaran VP, Kumaravel A, Saravanakumar SS. Characterization of new natural cellulosic fiber from Acacia leucophloea bark. International Journal of Polymer Analysis and Characterization. 2015;20(4):367-76.

34. Lun LW, Gunny AA, Kasim FH, Arbain D. Fourier transform infrared spectroscopy (FTIR) analysis of paddy straw pulp treated using deep eutectic solvent. InAIP Conference Proceedings 2017 (Vol. 1835, No. 1, p. 020049). AIP Publishing LLC.

35. Hospodarova V, Singovszka E, Stevulova N. Characterization of cellulosic fibers by FTIR spectroscopy for their further implementation to building materials. American journal of analytical chemistry. 2018;9(6):303-10.

36. Senthamaraikannan P, Saravanakumar SS, Arthanarieswaran VP, Sugumaran P. Physico-chemical properties of new cellulosic fibers from the bark of Acacia planifrons. International Journal of Polymer Analysis and Characterization. 2016;21(3):207-13.

37. Oliveira E, Santos J, Goncalves AP, Mattedi S, Jose N. Characterization of the rambutan peel fiber (*Nephelium lappaceum*) as a lignocellulosic material for technological applications. Chemical Engineering Transactions. 2016;50:391-6.

38. Rowell RM, 2012. Handbook of Wood Chemistry and Wood Composites. 1st ed. Florida: CRC press.

39. Ramawat KG, Merillon JM. Polysaccharides: bioactivity and biotechnology. Springer; 2015.