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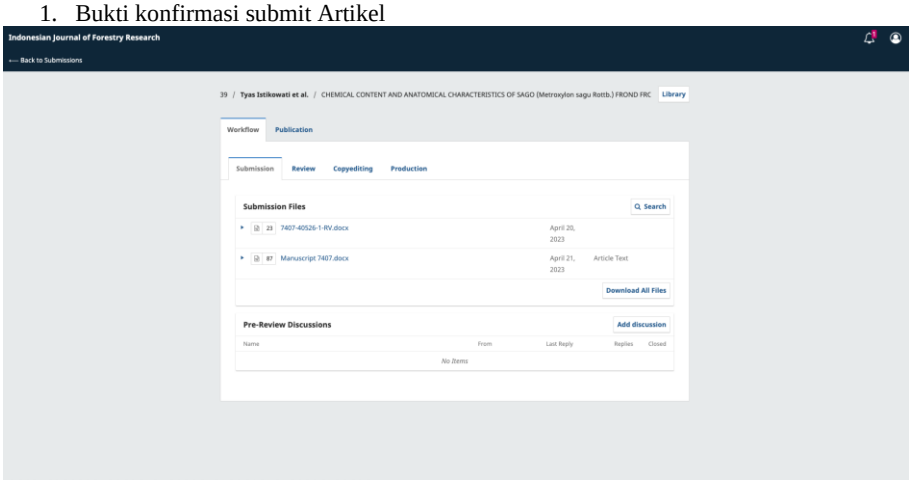

CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO FROND FROM SOUTH KALIMANTAN, INDONESIA

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO FROND FROM SOUTH KALIMANTAN, INDONESIA. This study aims to evaluate the suitability of sago palm waste as a fiber raw material in terms of its chemical content and anatomical characteristics. The chemical content analysis of its extractive components, lignin, holocellulose, α-cellulose, and hemicellulose was carried out using sago frond powder with a size of 40 - 60 mesh. Subsequently, functional group analysis was performed using FTIR, while anatomical characterization was carried out by calculating the fiber length and diameter, lumen diameter, fiber derivative values as well as cell wall thickness using a microscope connected to a digital camera. The results showed that sago frond contains 31.6% α-cellulose and 38% lignin. The α-cellulose content was within the standard range for non-timber forest products, but the lignin content had a relatively high value. Based on the derived value, namely class II, sago frond can be used as pulp and paper raw materials but needs pretreatment for the delignification process.

Keywords: Sago Palm (*Metroxylon sagu* Rottb.), Anatomical Characteristic, Chemical Content, FTIR

KANDUNGAN KIMIA DAN KARAKTERISTIK ANATOMI BATANG SAGU DARI KALIMANTAN SELATAN. Penelitian ini bertujuan untuk menganalisis kesesuaian limbah tanamana sagu (pelepah sagu) sebagai bahan baku pulp dan kertas dilihat dari kandungan kimia pelepah sagu dan karakteristik anatominya. Analisis kimia menggunakan serbuk pelepah dengan ukuran 40 - 60 mesh. Kandungan kimia berupa ekstraktif, lignin, holoselulosa, α -Selulosa, dan hemiselulosa dianalisis dan juga analisis menggunakan FTIR. Karakteristik anatomi dilakukan dengan melakukan penghitungan panjang dan diameter serat, diameter lumen, dan tebal dinding sel menggunakan mikroskop yang terhubung dengan kamera digital dan selanjutnya dilakukan perhitungan nilai turunan seratnya. Pengambilan gambar menggunakan *Scanning Electron Microscop* (SEM) juga dilakukan dengan beberapa perbesaran yang berbeda. Dari penelitian diperoleh data bahwa kadar ∝-selulosa pelepah sagu sebesar 31,585% dengan kandungan lignin 37,996%. Kandungan ∝-selulosa pelepah sagu menunjukkan nilai standar pada produk hasil hutan bukan kayu namun kadar ligninnya menunjukkan nilai yang relatif tinggi. Dari nilai turunan serat pelepah sagu termasuk kelas II sehingga memiliki kesesuaian untuk bahan baku pulp dan kertas namun perlu perlakuan awal untuk proses delignifikasi.

Kata kunci: Sagu (*Metroxylon sagu* Rottb.), karakteristik anatomi, kandungan kimia, FTIR

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I. INTRODUCTION

Sago plants are classified as abundant non-timber forest products in Kalimantan, where they grow in swamps and along river banks. In 2017, the plantation area in South and West Kalimantan was 6,548 ha and 1,767 ha, respectively. Furthermore, the total production from the two provinces was 2,885 ha/3,723 tons and 390 ha/308 tons (Directorate General Plantation 2017). Sago plant has tall stems with a wide diameter. During its processing to obtain flour, some wastes are often produced from the parts, which have not been optimally used, namely the frond and bark. The remaining part is a source of cellulose, which can be used as a raw material for the pulp and paper industry.

Fiber sources as raw material for pulp can be divided into two groups, namely wood and non-wood types. In Indonesia, the pulp industry often obtains its raw materials from broadleaf wood. The fibers produced by these species are relatively short with a range of 0.6-1.9 mm (Pakala, 2001). Short fibers often produce a homogeneous and perfectly mixed pulp, hence, they can be used to manufacture paper with a smooth surface, high opacity, improved printing quality, and high flexibility. However, these papers have low strength, specifically in their tear and tensile indexes (Wimmer et al 2002; Fiserova et al 2009). To increase their strength, it is necessary to add long fibers to the pulp mixture. Long fibers can be obtained from needle-leaf wood and non-timber forest products, such as frond, bagasse, bamboo, jute, straw, and agricultural waste.

Sago frond and bark are abundant sources of cellulose in South Kalimantan. Several studies were also carried out on the wastes, such as the application of the frond as an alternative adsorbent material and charcoal (Wahi et al 2014; Johan et al 2021), but none explored its usage as an alternative mixture for raw materials in the pulp and paper industry and particle board. Therefore, an analysis of its chemical content and anatomical characteristics as a source for pulp and paper raw materials and particle board were carried out in this study. The use of the wastes can increase their value and improve the quality.×

II. MATERIAL AND METHOD

A. *Materials*

Material used for this research was frond of sago, acetic acid (CH_3COOH), sulfuric acid (H_2SO_4), benzene (C_6H_6), nitrit acid (HNO_3), aceton (CH_3COH_3), ethanol (C_2H_5OH), 1% and 17,5% of natrium hydroxide, distillated water, xylol, and safranin. The equipment used in this study was electric microscope, desiccator, water bath, hot plate stirrer, oven, electronic balancing, hammer mill, 40 and 60 mesh sieve, magnetic stirrer, beaker glass, Erlenmeyer, object and cover glass, etc.

B. *Procedure:*

The sago frond waste was produced in the form of chips with a size of 3 cm × 3 cm × 2 mm. The chemical analysis and FTIR were carried out using powder with a size of 40 - 60 mesh. Furthermore, the sample used for the measurement of fiber dimensions was in the form of a stick, which was macerated using the Schultze method. The softened sample was then stained with safranin and washed in alcohol with a graded concentration, followed by immersion in xylol.

Moisture Content

The sample was weighed and placed in a weighing bottle with a known weight. It was then dried in an oven at 103 ± 2°C for 12 hours until it was constant. Moisture Content (MC) was then calculated using the formula (1):

$$MC = \frac{Innitial\ mass - Oven\ dry\ mass}{Oven\ dry\ mass} \times 100\% \quad \text{.....(1)}$$

Determination of Chemical Components

a. Extractive Content in Ethanol – Benzene

The extractive content dissolved in benzene ethanol was analyzed and calculated standard methods (JWRS, 2000).

b. Lignin Content

The lignin content was obtained from the extractive-free samples, which were placed in a beaker. Subsequently, 30 mL of 98% H_2SO_4 was added and it was allowed to stand at room temperature for one day. The solution was then boiled at 100°C for 60 minutes, while the filtrate was washed until the smell of sulfuric acid disappeared. The samples were dried in an oven at 103 ± 2°C to obtain a constant weight. The residue obtained from the extraction was the lignin content.

c. Holocellulose Content

A total of 1g of the extractive-free sample was weighed and placed into a 100 ml Erlenmeyer flask. Its moisture content was then measured, and used for the calculation of the holocellulose content. Furthermore, 40 ml of distilled water, 1.5 ml of 25% $NaClO_2$ (sodium chlorite), and 0.125 ml of 100% glacial acetic acid were added to the sample. The mixture was stirred and the Erlenmeyer flask was tightly closed, followed by heating in a water bath for 60 minutes at 80°C. It was then cooled in an ice bath and filtered using a weighed 1G3 filter glass. A total of 10 ml sample was added, followed by 25 ml of acetone. It was then dried in an oven at 103 ± 2°C for 1 day, after which it was cooled in a desiccator for 30 minutes and weighed.

d. α-Cellulose Content

The test of α-cellulose content in sago frond and bark was carried out in different steps. An empty 1G3 funnel filter was dried in an oven at 103 ± 2°C, cooled in a desiccator for 30 minutes, and the oven-dry weight was measured. A total of 0.5 g of the holocellulose sample was weighed and placed in a ± 20 mL wide-mouth vial. Subsequently, 6.25 ml of 17% NaOH was added followed by stirring using a magnetic stirrer for 15 minutes. The mixture was then left for 30 minutes, and 8.25 ml of 17% NaOH was added. It was stirred using a magnetic stirrer for 5 minutes and left for 60 minutes. The final mixture was then filtered using a IG3 filter glass, followed by rinsing with 25 ml of 8.3% NaOH and 100 ml of distilled water. The hose attached to the vacuum bottle was removed and the sample in IG3 was placed in 10 ml of 10% acetic acid for 3 minutes. Subsequently, the hose was reconnected and left until the entire solution was sucked out. The sample was then rinsed with distilled water until it became neutral, as indicated by the blue litmus paper attached. It was dried in an oven at 103 ± 2°C for 24 hours, removed, cooled in a desiccator for 30 minutes, and weighed.

e. Hemicellulose Content

The hemicellulose content was calculated by subtracting the holocellulose content from α-cellulose.

Determination of Anatomical properties and Derived Wood Properties

To determine anatomical properties, small stick of frond of sago were collected and macerated with Schulz's solution. Fifty fibre were measured under electronic microscope. The results were used to calculate determine wood properties. Runkel Ratio (Runkel, 1949), Slenderness Ratio (Malan, 1987), Muhlsteph's Ratio (Yahya 2010), Coeffitient of Rigidity (Tamalong 1961), and Flexibility Ratio (Malan, 1987) were calculated by following equation:

$$Runkel\ Ratio = \frac{Fiber\ wall\ thickness \times 2}{Fiber\ lumen\ diameter} \quad \text{.....(2)}$$

$$Slenderness\ Ratio = \frac{Fiber\ length}{Fiber\ diameter} \quad \text{.....(3)}$$

$$Muhlsteph's\ Ratio = \frac{kuadrat\ of\ fiber\ diameter - kuadrat\ of\ fiber\ lumen\ diameter}{kuadrat\ of\ fiber\ diameter} \quad \text{..(4)}$$

$$Coefficient\ of\ Rigidity = \frac{Fiber\ wall\ tickness}{Fiber\ diameter} \quad \text{.....(5)}$$

$$Flexilility\ coefficient = \frac{Fiber\ Lumen\ diameter}{Fiber\ diameter} \quad \text{.....(6)}$$

The Scanning Electron Microscope figures then were taken in different magnification of sago frond.

III. RESULT AND DISCUSSION

The chemical content analysis results of the sago frond showed the moisture (%), ethanol-benzene extractive (%), lignin (%), acid-soluble lignin (%), holocellulose (%), and ∝-cellulose (%) content as well as the FTIR.

A. Chemical content analysis

The results showed that the moisture content (MC) of sago frond was 75.434%. The value obtained can vary in different areas with the same plant species. Moisture content can also be affected by the dryness of the sample when it is powdered before baking. Water is needed by plants to transport nutrients and minerals. Determination of MC in the pulp and paper industry is often used to calculate the use of cooking chemicals in the pulping process.

The ethanol-benzene extractive content of the sago frond was 5.56% (Tabel 1), and it was lower compared to that of purun tikus *(Eleocharis dulcis)* extract, namely 9.53%. High values in pulp raw materials are not expected because it causes difficulty in the breakdown of fiber during the cooking process (Sunardi & Istikowati, 2012). A low extractive content of sago frond, which makes it suitable as a pulp and paper raw material and fiber-based product such as fiber biocomposite. This is because extractive substances can cause pitch, namely spots on the paper produced, and the tools used can easily be dull. High levels can also inhibit the entry of chemicals during the pulp ripening process (Sugesty at al 2015: Istikowati et al 2016).

Table 1 Chemical content of non-wood materials

Parameters	Chemical content (%)		
	Sago frond	Purun Tikus[1]	Pandan Rasau[2]
Moisture Content	75.43	92.68	96.07
Extractive content	5.56	9.53	4.60
Lignin content	37.99	26.40	31.67
Holocellulosa	55.63	-	58.73

α-Cellulosa	31.59	-	27.06
Hemicellulosa	24.05	-	31.67

Note: [1], Sunardi & Istikowati (2012); [2], Herlina et al. (2019)

Furthermore, the lignin content of sago frond was 42.02% (Table 1), which was higher than *pandan rasau* and almost the same as reeds lignin, namely 31.67% and 31.29%, respectively. The value obtained was also higher compared to woods widely used as raw material for pulp and paper, namely *A. mangium*, sengon, and *E. urophylla* with content of 31.30%23.77%, and 24.31%, respectively (Karlinasari et al. 2010; Yahya et al. 2010; Nasdy 2013). Sago frond lignin content can be categorized as high, which is not needed in the industry because it can increase the need for cooking chemicals, thereby making it less economical (Putra et al. 2018). Lignin is a component that must be removed in the pulping process, and this makes the wood cells break down easily into single fibers. Its presence in the pulp can inhibit hydrogen bonding, cause an adverse effect on color, and increase the stiffness of the paper sheets (Maximora et al. 2001).

High holocellulose content is needed in the manufacture of pulp because it increases the yield (Casey, 1980). The value obtained for sago fronds in this study was 55.63%. Cellulose-based materials with high holocellulose content are good for pulp and paper because they help to increase the yields during the pulping process.

Hemicellulose acts as a binder to the paper-forming fibers, hence, a sufficient amount helps to produce quality papers (Casey, 1980). A high content value of 24.048% was obtained from sago frond and the normal range for woody plants is 15-19% (Prawirohatmodjo 1977). The pulp yield and physical properties of the sheet produced are often affected by the hemicellulose content. However, very high levels are not suitable for the pulping process because the time and power required for milling and separating the fibers during mechanical treatment also increase (Sugesty et al. 2015).

B. Fourier Transform Infra-Red (FTIR)

FTIR is a spectrum measurement technique based on the material's response to electromagnetic radiation. It is often used for qualitative and quantitative analysis to determine the groups of organic and inorganic compounds in a sample. The measurement can also be used to determine the molecular structure of a compound. The results of the FTIR wave spectrum on the extractive-free sago frond are presented in Figure 1.

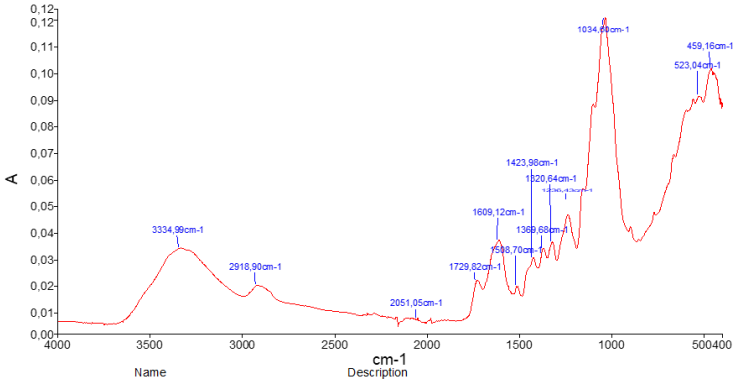

Fig. 1. FTIR spectrum of sago frond

Functional group analysis was carried out to determine the holocellulose, α-cellulose, hemicellulose, and lignin content of the sample. Furthermore, the groups in organic compounds can absorb electromagnetic radiation at wavelengths of 2.5-25 m or wave numbers of 400-4000 cm^{-1} (Sutiya et al. 2012). The data of the IR spectrum wave and its interpretation are presented in Tables 2 and 3, respectively.

The O-H functional group is the cellulose hydroxyl obtained from the spectrum of the sample, as shown in Table 3. The C=C group extends the aromatic ring (lignin) to the sago frond. The wave number for the C-H bonding of cellulose, hemicellulose, and pectin was 459.16 cm^{-1}.

FTIR presents qualitative data, in the form of a spectrum that shows peaks or wave numbers. The wave numbers, which were interpreted into functional groups and chemical bonds are used to determine the chemical content of a material. The spectrum of the sago frond shows its lignin, hemicellulose, and cellulose content. The extractive wave value does not appear in the FTIR test because it uses an extractive-free sample. The results are in line with the chemical component tests that sago frond contains 37.99% lignin, 55.63% holocellulose, 24.05% hemicellulose, and 31.59% α-cellulose.

Tabel 2. Wave spectrum of Sago Frond

No.	Wave number (cm^{-1})	Functional group
1.	3,300	O-H
2.	3,400	N-H
3.	<3,000	C-H sp^3
4.	>3,000	C-H sp^2
5.	3,300	C-H sp
6.	2,850 & 2,750	C-H aldehid
7.	2,250	C=N
8.	2,100	C=C
9.	1,300-1,000	C-O
10.	800-600	C-Cl
11.	~1,460	CH_2 bending
12.	~1,380	CH_3 bending

Spectrum of sago frond	Note
3,334.99	Shows the O-H fuctional group of the hydroxyl group (α-cellulose)
2,918.90	Shows C-H from metal group
2,051.05	C=C Aromatic ring group (lignin)
1,729.82	C=O Acelyt group, carboxylic acid (hemicellulosa)
1,609.12	C=C Aromatic ring group (lignin)
1,508.70	C=C Aromatic ring group (lignin)
1,423.98	C-H deformation (lignin, hemicellulosa)
1,369.68	C-H vibration (α-cellulose)
1,320.64	C-H vibration (α-cellulose)
2,361.43	-
1,034.60	Shows C-O vibration from β-1,4-glikosida bonding (α-cellulose)
523.04	C-H deformation (lignin, hemicellulose, pectin)
459.16	C-H deformation (lignin, hemicellulose, pectin)

Table 3. Intrepretation of Infra Red Wave Spectrum

C. Anatomical Characteristics

Dimensions of the sago frond measured include fiber length and diameter, lumen diameter, as well as cell wall thickness. The results of the average measurement of fiber dimensions were used to obtain its derivative value, and they have a positive correlation. The measured derivative values include the Runkel ratio, slenderness, muhsteph ratio, coefficient of rigidity (stiffness), and flexibility ratio. The results of the dimension measurement of the sago bark and frond fiber are presented in Table 4.

Tabel 4. Fiber dimention of non-wood materials

Type	Fiber Dimention			
	Fibre Length (mm)	Fiber Diameter (μm)	Lumen Diameter (μm)	Fiber Wall Tickness (μm)
Sago frond	2.11	12.77	5.92	3.61
Pandan Rasau[2]	1.56	11.10	6.80	2.50
Reed[2]	2.19	20.00	8.75	5.63
Purun Tikus[3]	1.68	5.89	2.68	1.61

Note: Note: [1], Herlina et al. (2019); [2], Silitonga et al (1972); [3], Sunardi & Istikowati (2012)

Sago frond is a lignocellulosic natural fiber with a long length, and it is longer than pandan rasau and purun rat, while it has almost the same length as reed fibers. Long fibers often have stronger bonds, and they are not easily separated. Furthermore, the folding strength of the paper was high and it was not easy to tear. Excessively long fibers can lead to the production of rough paper, hence, it is important to reduce the length to increase the smoothness of the product.

The diameter of the sago frond fiber was 12.77 μm, and it was classified as slender. This indicates that the sample is suitable for pulp because it can produce thinner and stronger paper (Sunardi &

Istikowati, 2012). The slender fibers are easily interwoven and form sheets of paper with good properties, which are not easily torn.

The lumen diameter of the sago frond was 12.77 μm, and this value is higher than purun rat and bamboo betung, but lower compared to reeds. The fibers also have thinner cell walls compared to reeds and bamboo betung. Thin walls are easily flattened, and this provides a large surface area for bonding between fibers. This condition causes low tear values, but high folding, breaking, and tensile strengths (Casey 1980).

D. Derived Wood Properties

Derived wood properties were obtained by comparing the results of the dimension measurements. Derived wood was used to predict the quality of the pulp to be produced. Moreover, the derived value of sago bark and frond are presented in Table 5. The requirements and value of wood fiber as raw material for pulp and paper are shown in Table 6. The average fiber length of sago frond fibers 2.11 mm, which can be categorized as class II. Fiber length of sago frond are almost similar with reed and longer than pandan rasau and purun tikus, as shown in Table 4. The length of fiber produce paper with high strength quality.

Table 5. Derived wood properties of non-wood fiber

Derived wood	Sago Frond	Pandan Rasau[1]	Reed[2]	Purun tikus[3]
Runkel Ratio	1.30	0.72	1.29	1.20
Slenderness Ratio	164.50	140.54	109.37	285.45
Muhsteph Ratio (%)	81.24	166.46	42.24	38.40
Coefficient of Rigidity	0.28	0.2	0.28	0.27
Flexibility Ratio	0.43	0.61	0.44	0.45

Note: [1], Herlina et al. (2019); [2], Silitonga et al (1972); [3], Sunardi & Istikowati (2012)

Table 6. Standard of Derived Wood Properties (Silitonga 1972)

	Class I		Class II		Class III		Class IV	
	Requirement	Score	Requirement	Score	Requirement	Score	Requirement	Score
Fibre Length (mm)	2.2	100	1.6-2.2	75	0.9-1.6	50	<0.9	25
Runkel Ratio	<0.25	100	0.25-0.5	75	0.5-1.0	50	>1.00	25
Mulhstep Ratio(%)	<30	100	30-60	75	60-80	50	>80	25
Slenderness Ratio	>90	100	70-90	75	40-70	50	<40	25
Fleksibility Ratio	>0.80	100	0.6-0.8	75	0.4-0.6	50	<0.40	25
Stifness Ratio	<0.1	100	0.1-0.15	75	0.15-0.2	50	>0.20	25
Total		600		450		300		150
Score Requirement	451-600		301-450		151-300		150	

The Runkel ratio of sago frond was 1.30 and it can be categorized as class IV. A small ratio is important during the manufacturing process, because it produces paper with strong fiber bonds and flat sheets, while a high value reduces flexibility and produces stiff paper (Silitonga 1972).

The slenderness ratio of sago frond was 164.50, hence, it can be categorized as class 1. The value obtained was higher than pandan rasau, purun tikus and reeds fibers. Sago frond has a long fiber,

which made the weaving power and bonding very strong. Furthermore, a high value is related to the smoothness of the paper produced. High weaving power has a good influence on the tensile strength and breakage for paper or filler in biocomposites (Sugesty et al. 2015).

The Muhsteph ratio of sago frond was 81.24%, and it was categorized as class III. Paper produced from a high ratio has a rough surface, low squeezing strength, and is not plastic. Based on the value obtained, the fibers are not suitable for writing paper, but it can be used to produce wrapping or art paper. The coefficient of rigidity was 0.28, and it was categorized in class IV. The magnitude of this value is related to the stiffness of the paper produced. The higher the coefficient of rigidity, the higher the stiffness. The paper produced from this fibers is expected to have low tensile strength.

The flexibility ratio obtained was 0.43, and it was categorized in class III. A high ratio can produce papers that are more flexible and less stiff. The overall value of sago frond fiber derivatives was 325, and it was categorized in class II. Based on the properties, the can be used as an alternative raw material for pulp and paper.

Morphological characterization of sago frond using SEM aims to observe the surface roughness. Based on the SEM photo obtained, the surface shows many cavities with thin cell walls (Figures 2).

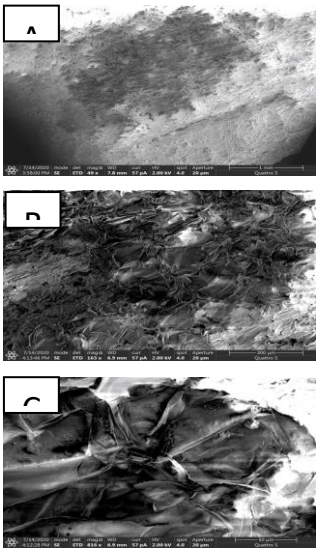

Fig. 2. Scanning Electron Microscope (SEM) of sago frond. Note: A, B, C = SEM of sago frond with magnification 30, 100, dan 500, respectively

IV. CONCLUSION

The α -cellulose and lignin content of sago frond were 31.59% and 37.99%, respectively. Furthermore, the amount of α -cellulose in the sample showed a standard value in non-timber forest products, but the lignin was relatively high. Based on the fiber derivatives, the sago palm was classified as class II. This indicates that it is suitable as pulp and paper raw and product based fibres materials, but needs pretreatment for lignin removal.

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Manuscript Title : Chemical Content and Anatomical Characteristics of Sago Frond from South Kalimantan, Indonesia

Manuscript code : 7407/2022

Evaluation	Reviewer Comments
The originality of the subject matter, and whether the manuscript would be of interest to the international, academic and practitioner readership of the IJFR	It is interesteing for international readers
The theoretical contribution made by the manuscript	Moderate
Does the manuscript draws on an appropriate range and depth of literature?	Yes
Does the methods employed are rigorous, ethical, and suitable for the topic under investigation?	Yes
Do the findings presented are subjected to suitable analysis and sound conclusions drawn?	Yes
Does the manuscript clearly identify any implications for future research? Are these implications consistent with the findings and conclusions of the manuscript?	No

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Some suggestions have not been addressed by authors in the previous review :

Introduction
- The botanical name should be mentioned
- Basic properties of sagoo from previous research should be mentioned

Method
- More detail description of palm frond material (location, condition, part, etc). This version is not sufficcient information
- the ratio between benzene ethanol (in Extractive Content in Ethanol – Benzene) should be mentioned

Discussion
The low sugar content and higher lognin content results should be discussed and what is the recommendation for pulping process and what paper products (not only pretreatment for the delignification) suitable for such condition

3.

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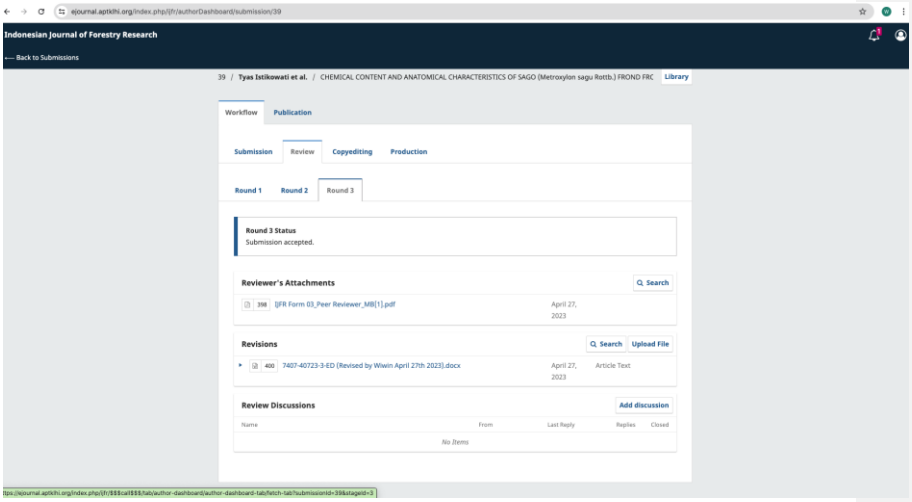
Date 1 April 2023

4.



CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA. This study aims to evaluate the suitability of sago palm waste as a fiber raw material in terms of its chemical content and anatomical

characteristics. The chemical content analysis of its extractive components, lignin, holocellulose, α-cellulose, and hemicellulose was carried out using sago frond powder with a size of 40 - 60 mesh. Subsequently, functional group analysis was performed using FTIR, while anatomical characterization was carried out by calculating the fiber length and diameter, lumen diameter, fiber derivative values as well as cell wall thickness using a microscope connected to a digital camera. *Scanning Electron Microscop* (SEM) pictures were taken in different magnifications. The results showed that sago frond contains 31.6% α-cellulose and 38% lignin. The α-cellulose content was within the standard range for non-timber forest products, but the lignin content had a relatively high value. Based on the derived value, namely class II, sago frond can be used as pulp and paper raw materials but needs pretreatment for the delignification process.

Keywords: Sago Palm (*Metroxylon sagu* Rottb.), Anatomical Characteristic, Chemical Content, FTIR

KANDUNGAN KIMIA DAN KARAKTERISTIK ANATOMI BATANG SAGU (*Metroxylon sagu* Rottb.) DARI KALIMANTAN SELATAN. Penelitian ini bertujuan untuk menganalisis kesesuaian limbah tanaman sagu (pelepah sagu) sebagai bahan baku pulp dan kertas dilihat dari kandungan kimia pelepah sagu dan karakteristik anatominya. Analisis kimia menggunakan serbuk pelepah dengan ukuran 40 - 60 mesh. Kandungan kimia berupa ekstraktif, lignin, holoselulosa, α -Selulosa, dan hemiselulosa dianalisis dan juga analisis menggunakan FTIR. Karakteristik anatomi dilakukan dengan melakukan penghitungan panjang dan diameter serat, diameter lumen, dan tebal dinding sel menggunakan mikroskop yang terhubung dengan kamera digital dan selanjutnya dilakukan perhitungan nilai turunan seratnya. Pengambilan gambar menggunakan *Scanning Electron Microscop* (SEM) juga dilakukan dengan beberapa perbesaran yang berbeda. Dari penelitian diperoleh data bahwa kadar ∝-selulosa pelepah sagu sebesar 31,585% dengan kandungan lignin 37,996%. Kandungan ∝-selulosa pelepah sagu menunjukkan nilai standar pada produk hasil hutan bukan kayu namun kadar ligninnya menunjukkan nilai yang relatif tinggi. Dari nilai turunan serat pelepah sagu termasuk kelas II sehingga memiliki kesesuaian untuk bahan baku pulp dan kertas namun perlu perlakuan awal untuk proses delignifikasi.

Kata kunci: Sagu (*Metroxylon sagu* Rottb.), karakteristik anatomi, kandungan kimia, FTIR

V. INTRODUCTION

Sago plants (*Metroxylon sagu* Rottb.) are classified as abundant non-timber forest products in Kalimantan, where they grow in swamps and along river banks. In 2022, the plantation area in South Kalimantan was 7,857 ha with the total production was 4,511 ton/ha (Saputra et al., 2022). Sago plant has tall stems with a wide diameter. During its processing to obtain flour, some wastes are often produced from the parts, which have not been optimally used, namely the frond and bark. The remaining part is a source of cellulose, which can be used as a raw material for the pulp and paper industry.

Fiber sources as raw material for pulp can be divided into two groups, namely wood and non-wood types. In Indonesia, the pulp industry often obtains its raw materials from broadleaf wood. The fibers produced by these species are relatively short with a range of 0.76-2.9 mm (El-Sayed, 2020). Short fibers often produce a homogeneous and perfectly mixed pulp, hence, they can be used to manufacture paper with a smooth surface, high opacity, improved printing quality, and high flexibility. However, these papers have low strength, specifically in their tear and tensile indexes (Fiserova et al 2009; Yahya et al 2019). To increase their strength, it is necessary to add long fibers to the pulp mixture. Long fibers can be obtained from needle-leaf wood and non-timber forest products, such as frond, bagasse, bamboo, jute, straw, and agricultural waste.

Sago frond and bark are abundant sources of cellulose in South Kalimantan. Several studies were also carried out on the wastes, such as the application of the frond as an alternative adsorbent material and charcoal (Wahi et al 2014; Johan et al 2021), but none explored its usage as an alternative mixture for raw materials in the pulp and paper industry and particle board. The major component of sago frond is crude fiber and carbohydrates with a value 17.90%-34.44% and 51.44%-72.87%, respectively (Marvie and Sunarti,2021). Therefore, an analysis of its chemical content and anatomical characteristics as a source for pulp and paper raw materials and particle board were carried out in this study. The use of the wastes can increase their value and improve the quality.

VI. MATERIAL AND METHOD

A. *Materials*

Material used for this research was frond of sago (*M. sagu Rottb.*), acetic acid (CH_3COOH), sulfuric acid (H_2SO_4), benzene (C_6H_6), nitrite acid (HNO_3), acetone (CH_3COH_3), ethanol (C_2H_5OH), 1% and 17,5% of natrium hydroxide, distillated water, xylol, and safranin. The equipment used in this study was electric microscope, desiccator, water bath, hot plate stirrer, oven, electronic balancing, hammer mill, 40 and 60 mesh sieve, magnetic stirrer, beaker glass, Erlenmeyer, object and cover glass, etc.

B. *Procedure:*

The sago frond waste was collected from Sungai Tabuk village, Banjar Regency, South Kalimantan, Indonesia. *About 2 meters of sago frond from the base were collected.* It was produced in the form of chips with a size of 3 cm × 3 cm × 2 mm and then powdered. The chemical analysis and FTIR (Shimadzu FTIR Prestige-21) were carried out using powder with a size of 40 - 60 mesh. The sample placed in FTIR spectrometer, then the FTIR instrument sends infrared radiation of about 10.000 to 100 cm^{-1} through a sample, with some radiation absorbed and some passed through. The absorbed radiation is converted into vibrational energy. The resulting signal at the detector

presents as a spectrum representing a molecular fingerprint of sample. Each chemical structure will produce a unique spectral fingerprint and chemical structure can be identified. Furthermore, the sample used for the measurement of fiber dimensions was in the form of a stick, which was macerated using the Schultze method. The softened sample was then stained with safranin and washed in alcohol with a graded concentration, followed by immersion in xylol.

Moisture Content

The sample was weighed and placed in a weighing bottle with a known weight. It was then dried in an oven at 103 ± 2°C for 12 hours until it was constant. Moisture Content (MC) was then calculated using the formula (1):

$$MC = \frac{Innitial\ mass - Oven\ dry\ mass}{Oven\ dry\ mass} \times 100\% \quad \text{.....(1)}$$

Determination of Chemical Components

f. Extractive Content in Ethanol – Benzene

To determine the amount of organic solvent extract, 2.5 g sample was extracted with 120 mL mixture of 95% ethanol and benzene (1 : 2, v : v) for 6 hours using a Soxhlet extractor. The extractive content dissolved in benzene ethanol was calculated using standard methods (JWRS, 2000).

g. Lignin Content

The lignin content was obtained from the extractive-free samples, which were placed in a beaker. Subsequently, 30 mL of 98% H_2SO_4 was added and it was allowed to stand at room temperature for one day. The solution was then boiled at 100°C for 60 minutes, while the filtrate was washed until the smell of sulfuric acid disappeared. The samples were dried in an oven at 103 ± 2°C to obtain a constant weight. The residue obtained from the extraction was the lignin content.

h. Holocellulose Content

A total of 1g of the extractive-free sample was weighed and placed into a 100 ml Erlenmeyer flask. Its moisture content was then measured, and used for the calculation of the holocellulose content. Furthermore, 40 ml of distilled water, 1.5 ml of 25% $NaClO_2$ (sodium chlorite), and 0.125 ml of 100% glacial acetic acid were added to the sample. The mixture was stirred and the Erlenmeyer flask was tightly closed, followed by heating in a water bath for 60 minutes at 80°C. It was then cooled in an ice bath and filtered using a weighed 1G3 filter glass. A total of 10 ml sample was added, followed by 25 ml of acetone. It was then dried in an oven at 103 ± 2°C for 1 day, after which it was cooled in a desiccator for 30 minutes and weighed.

i. α-Cellulose Content

The test of α-cellulose content in sago frond and bark was carried out in different steps. An empty 1G3 funnel filter was dried in an oven at 103 ± 2°C, cooled in a desiccator for 30 minutes, and the oven-dry weight was measured. A total of 0.5 g of the holocellulose sample was weighed and placed in a ± 20 mL wide-mouth vial. Subsequently, 6.25 ml of 17% NaOH was added followed by stirring using a magnetic stirrer for 15 minutes. The mixture was then left for 30 minutes, and 8.25 ml of 17% NaOH was added. It was stirred using a magnetic stirrer for 5 minutes and left for 60 minutes. The final mixture was then filtered using a IG3 filter glass, followed by rinsing with 25 ml of 8.3% NaOH and 100 ml of distilled water. The hose attached to the vacuum bottle was removed and the sample in IG3 was placed in 10 ml of 10% acetic acid for 3 minutes.

Subsequently, the hose was reconnected and left until the entire solution was sucked out. The sample was then rinsed with distilled water until it became neutral, as indicated by the blue litmus paper attached. It was dried in an oven at 103 ± 2°C for 24 hours, removed, cooled in a desiccator for 30 minutes, and weighed.

j. Hemicellulose Content

The hemicellulose content was calculated by subtracting the holocellulose content from α-cellulose.

Measurement of Fiber Dimension and Derived Fiber

To determine anatomical properties, small stick of frond of sago were collected and macerated with Schulz's solution. Fifty fibre were measured under electronic microscope. The results were used to calculate determine wood properties. Runkel Ratio, Slenderness Ratio, Muhlsteph's Ratio, Coeffitient of Rigidity), and Flexibility Ratio were calculated by following equation in (Istikowati el al., 2016a):

$$Runkel\ Ratio = \frac{Fiber\ wall\ thickness \times 2}{Fiber\ lumen\ diameter} \quad \text{.....(2)}$$

$$Slenderness\ Ratio = \frac{Fiber\ length}{Fiber\ diameter} \quad \text{.....(3)}$$

$$Muhlsteph's\ Ratio = \frac{kuadrat\ of\ fiber\ diameter - kuadrat\ of\ fiber\ lumen\ diameter}{kuadrat\ of\ fiber\ diameter} \quad \text{..(4)}$$

$$Coefficient\ of\ Rigidity = \frac{Fiber\ wall\ tickness}{Fiber\ diameter} \quad \text{.....(5)}$$

$$Flexilility\ coefficient = \frac{Fiber\ Lumen\ diameter}{Fiber\ diameter} \quad \text{.....(6)}$$

The Scanning Electron Microscope figures then were taken in different magnification of sago frond.

VII. RESULT AND DISCUSSION

The chemical content analysis results of the sago frond showed the moisture (%), ethanol-benzene extractive (%), lignin (%), acid-soluble lignin (%), holocellulose (%), and ∝-cellulose (%) content as well as the FTIR.

A. Chemical content analysis

The results showed that the moisture content (MC) of sago frond was 75.434%. The value obtained can vary in different areas with the same plant species. Moisture content can also be affected by the dryness of the sample when it is powdered before baking. Water is needed by plants to transport nutrients and minerals. Determination of MC in the pulp and paper industry is often used to calculate the use of cooking chemicals in the pulping process.

The ethanol-benzene extractive content of the sago frond was 5.56% (Tabel 1), and it was lower compared to that of purun tikus *(Eleocharis dulcis)* extract, namely 9.53%. High values in pulp raw materials are not expected because it causes difficulty in the breakdown of fiber during the cooking process (Sunardi & Istikowati, 2012). A low extractive content of sago frond, which makes it suitable as a pulp and paper raw material and fiber-based product such as fiber biocomposite. This

is because extractive substances can cause pitch, namely spots on the paper produced, and the tools used can easily be dull. High levels can also inhibit the entry of chemicals during the pulp ripening process (Sugesty at al 2015: Istikowati et al 2016b).

Table 1 Chemical content of non-wood materials

Parameters	Chemical content (%)				
	Sago frond	Purun Tikus[1]	Pandan Rasau[2]	Salacca Frond[3]	Nipa frond[4]
Moisture Content	75.43	92.68	96.07	-	-
Extractive content	5.56	9.53	4.60	7.8	1.9
Lignin content	37.99	26.40	31.67	23	17,8
Holocellulosa	55.63	-	58.73	57.6	61,6
α-Cellulosa	31.59	-	27.06	29.3	35,1
Hemicellulosa	24.05	-	31.67	28.3	26,4

Note: [1], Sunardi & Istikowati (2012); [2], Herlina et al. (2019); [3], Hakim et al; [4], Tamunaidu & Saka (2011)

Furthermore, the lignin content of sago frond was 37.99% (Table 1), which was higher than *pandan rasau* and almost the same as reeds lignin, namely 31.67% and 31.29%, respectively. The value obtained was also higher compared to woods widely used as raw material for pulp and paper, namely *A. mangium*, sengon, and *E. urophylla* with content of 31.30%23.77%, and 24.31%, respectively (Karlinasari et al. 2010; Yahya et al. 2019; Nasdy 2013). Sago frond lignin content can be categorized as high, which is not needed in the industry because it can increase the need for cooking chemicals, thereby making it less economical (Putra et al. 2018). Lignin is a component that must be removed in the pulping process, and this makes the wood cells break down easily into single fibers. Its presence in the pulp can inhibit hydrogen bonding, cause an adverse effect on color, and increase the stiffness of the paper sheets (Sugesty et al. 2015). Material with low lignin content is more desirable for pulpwood because the content affects pulp yield as well as bleaching process, higher content of lignin in wood leading to lower pulp yield and paper strength (Istikowati et al., 2016b).

High holocellulose and α-cellulose content is needed in the manufacture of pulp because it increases the yield (Yahya et al., 2019). The valueof holocellulose and α-cellulose obtained for sago fronds in this study was 55.63% and 31.59%, respectively. Cellulose-based materials with high holocellulose content are good for pulp and paper because they help to increase the yields during the pulping process.

Hemicellulose acts as a binder to the paper-forming fibers, hence, a sufficient amount helps to produce quality papers (Yahya et al., 2019). The pulp yield and physical properties of the sheet produced are often affected by the hemicellulose content. However, very high levels are not suitable for the pulping process because the time and power required for milling and separating the fibers during mechanical treatment also increase (Sugesty et al. 2015).

B. Fourier Transform Infra-Red (FTIR)

FTIR is a spectrum measurement technique based on the material's response to electromagnetic radiation. It is often used for qualitative and quantitative analysis to determine the groups of organic and inorganic compounds in a sample. The measurement can also be used to determine the molecular structure of a compound. The results of the FTIR wave spectrum on the extractive-free sago frond are presented in Figure 1.

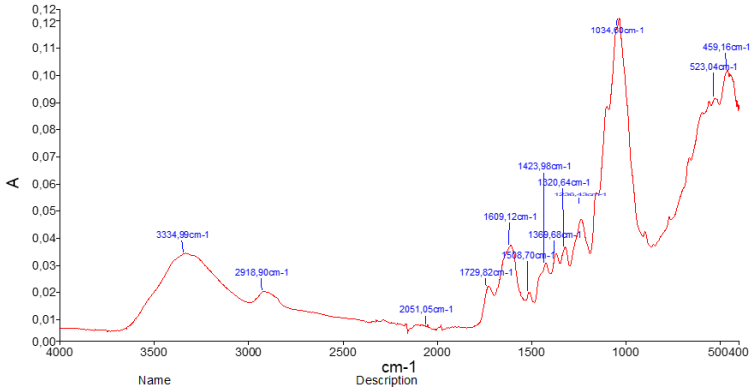

Fig. 1. FTIR spectrum of sago frond

Functional group analysis was carried out to determine the holocellulose, α-cellulose, hemicellulose, and lignin content of the sample. Furthermore, the groups in organic compounds can absorb electromagnetic radiation at wavelengths of 2.5-25 m or wave numbers of 400-4000 cm^{-1} (Sutiya et al. 2012). The data of the IR spectrum wave and its interpretation are presented in Tables 2 and 3, respectively.

The O-H functional group is the cellulose hydroxyl obtained from the spectrum of the sample, as shown in Table 3. The C=C group extends the aromatic ring (lignin) to the sago frond. The wave number for the C-H bonding of cellulose, hemicellulose, and pectin was 459.16 cm^{-1}.

FTIR presents qualitative data, in the form of a spectrum that shows peaks or wave numbers. The wave numbers, which were interpreted into functional groups and chemical bonds are used to determine the chemical content of a material. The spectrum of the sago frond shows its lignin, hemicellulose, and cellulose content. The extractive wave value does not appear in the FTIR test because it uses an extractive-free sample. The results are in line with the chemical component tests that sago frond contains 37.99% lignin, 55.63% holocellulose, 24.05% hemicellulose, and 31.59% α-cellulose.

Tabel 2. Wave spectrum of Sago Frond

No.	Wave number (cm^{-1})	Functional group
1.	3,300	O-H
2.	3,400	N-H
3.	<3,000	C-H sp^3
4.	>3,000	C-H sp^2
5.	3,300	C-H sp
6.	2,850 & 2,750	C-H aldehid
7.	2,250	C=N
8.	2,100	C=C
9.	1,300-1,000	C-O
10.	800-600	C-Cl
11.	~1,460	CH_2 bending
12.	~1,380	CH_3 bending

Table 3. Intrepretation of Infra Red Wave Spectrum

Spectrum of sago frond	Note
3,334.99	Shows the O-H fuctional group of the hydroxyl group (α-cellulose)
2,918.90	Shows C-H from metal group
2,051.05	C=C Aromatic ring group (lignin)
1,729.82	C=O Acelyt group, carboxylic acid (hemicellulosa)
1,609.12	C=C Aromatic ring group (lignin)
1,508.70	C=C Aromatic ring group (lignin)
1,423.98	C-H deformation (lignin, hemicellulosa)
1,369.68	C-H vibration (α-cellulose)
1,320.64	C-H vibration (α-cellulose)
2,361.43	-
1,034.60	Shows C-O vibration from β-1,4-glikosida bonding (α-cellulose)
523.04	C-H deformation (lignin, hemicellulose, pectin)
459.16	C-H deformation (lignin, hemicellulose, pectin)

C. Anatomical Characteristics

Dimensions of the sago frond measured include fiber length and diameter, lumen diameter, as well as cell wall thickness. The results of the average measurement of fiber dimensions were used to obtain its derivative value, and they have a positive correlation. The measured derivative values include the Runkel ratio, slenderness, muhsteph ratio, coefficient of rigidity (stiffness), and flexibility ratio. The results of the dimension measurement of the sago bark and frond fiber are presented in Table 4.

Tabel 4. Fiber dimention of non-wood materials

Type	Fiber Dimention			
	Fibre Length (mm)	Fiber Diameter (µm)	Lumen Diameter (µm)	Fiber Wall Tickness (µm)
Sago frond	2.11	12.77	5.92	3.61
Pandan Rasau[1]	1.56	11.10	6.80	2.50
Purun Tikus[2]	1.68	5.89	2.68	1.61
Palm oil[3]	1.07	28.15	22.57	2.79

Note: Note: [1], Herlina et al. (2019); [2], Sunardi & Istikowati (2012); [3], Yahya et al. (2019)

Sago frond is a lignocellulosic natural fiber with a long length, and it is longer than pandan rasau and purun rat, while it has almost the same length as reed fibers. Long fibers often have stronger bonds, and they are not easily separated. Furthermore, the folding strength of the paper was high and it was not easy to tear. Excessively long fibers can lead to the production of rough paper, hence, it is important to reduce the length to increase the smoothness of the product.

The diameter of the sago frond fiber was 12.77 µm, and it was classified as slender. This indicates that the sample is suitable for pulp because it can produce thinner and stronger paper (Sunardi & Istikowati, 2012). The slender fibers are easily interwoven and form sheets of paper with good properties, which are not easily torn.

The lumen diameter of the sago frond was 12.77 µm, and this value is higher than purun rat and bamboo betung, but lower compared to reeds. The fibers also have thinner cell walls compared to reeds and bamboo betung. Thin walls are easily flattened, and this provides a large surface area for bonding between fibers. This condition causes low tear values, but high folding, breaking, and tensile strengths (Yahya et al., 2019).

D. Derived Wood Properties

Derived wood properties were obtained by comparing the results of the dimension measurements. Derived wood was used to predict the quality of the pulp to be produced. Moreover, the derived value of sago bark and frond are presented in Table 5. The requirements and value of wood fiber as raw material for pulp and paper are shown in Table 6. The average fiber length of sago frond fibers 2.11 mm, which can be categorized as class II. Fiber length of sago frond are almost similar with reed and longer than pandan rasau and purun tikus, as shown in Table 4. The length of fiber produce paper with high strength quality.

Table 5. Derived wood properties of non-wood fiber

Derived wood	Sago Frond	Pandan Rasau[1]	Purun tikus[2]
Runkel Ratio	1.30	0.72	1.20
Slenderness Ratio	164.50	140.54	285.45
Muhsteph Ratio (%)	81.24	166.46	38.40
Coefficient of Rigidity	0.28	0.2	0.27
Flexibility Ratio	0.43	0.61	0.45

Note: [1], Herlina et al. (2019); [2], Sunardi & Istikowati (2012)

Table 6. Standard of Derived Wood Properties (Silitonga 1972)

	Class I		Class II		Class III		Class IV	
	Requirement	Score	Requirement	Score	Requirement	Score	Requirement	Score
Fibre Length (mm)	2.2	100	1.6-2.2	75	0.9-1.6	50	<0.9	25
Runkel Ratio	<0.25	100	0.25-0.5	75	0.5-1.0	50	>1.00	25
Mulhstep Ratio(%)	<30	100	30-60	75	60-80	50	>80	25
Slenderness Ratio	>90	100	70-90	75	40-70	50	<40	25
Fleksibility Ratio	>0.80	100	0.6-0.8	75	0.4-0.6	50	<0.40	25
Stifness Ratio	<0.1	100	0.1-0.15	75	0.15-0.2	50	>0.20	25
Total		600		450		300		150
Score Requirement	451-600		301-450		151-300		150	

The Runkel ratio of sago frond was 1.30 and it can be categorized as class IV. A small ratio is important during the manufacturing process, because it produces paper with strong fiber bonds and flat sheets, while a high value reduces flexibility and produces stiff paper (Istikowati et al., 2016b).

The slenderness ratio of sago frond was 164.50, hence, it can be categorized as class 1. The value obtained was higher than pandan rasau, purun tikus and reeds fibers. Sago frond has a long fiber, which made the weaving power and bonding very strong. Furthermore, a high value is related to the smoothness of the paper produced. High weaving power has a good influence on the tensile strength and breakage for paper or filler in biocomposites (Sugesty et al. 2015).

The Muhsteph ratio of sago frond was 81.24%, and it was categorized as class III. Paper produced from a high ratio has a rough surface, low squeezing strength, and is not plastic. Based on the value obtained, the fibers are not suitable for writing paper, but it can be used to produce wrapping or art paper. The coefficient of rigidity was 0.28, and it was categorized in class IV. The magnitude of this value is related to the stiffness of the paper produced. The higher the coefficient of rigidity, the higher the stiffness. The paper produced from this fibers is expected to have low tensile strength.

The flexibility ratio obtained was 0.43, and it was categorized in class III. A high ratio can produce papers that are more flexible and less stiff. The overall value of sago frond fiber derivatives was 325, and it was categorized in class II. Based on the properties, the can be used as an alternative raw material for pulp and paper.

The observation under SEM at high magnifications showed the 3D structure of sago frond in different magnifications. Morphological characterization of sago frond using SEM aims to observe the surface roughness. Based on the SEM photo obtained, the surface shows many cavities with thin cell walls (Figures 2). SEM images of sago frond showed the cells of sago frond, however it was not possible to differentiate among fiber and parenchyma.

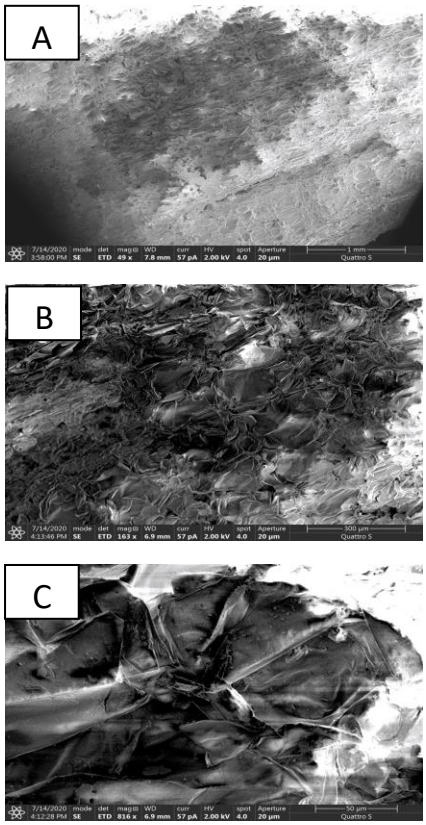

Fig. 2. Scanning Electron Microscope (SEM) of sago frond
Note: A, B, C = SEM of sago frond with magnification 30, 100, dan 500, respectively

VIII. CONCLUSION

The α -cellulose and lignin content of sago frond were 31.59% and 37.99%, respectively. Furthermore, the amount of α -cellulose in the sample showed a standard value in non-timber forest products, but the lignin was relatively high. Based on the fiber derivatives, the sago palm was classified as class II. This indicates that it is suitable as pulp and paper raw and product based fibres materials, but needs pretreatment for lignin removal.

ACKNOWLEDGEMENT

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA. This study aims to evaluate the suitability of sago palm waste as a fiber raw material in terms of its chemical content and anatomical characteristics. The chemical content analysis of its extractive components, lignin, holocellulose, α-cellulose, and hemicellulose, was carried out using sago frond powder with a size of 40 - 60 mesh. Subsequently, functional group analysis was performed using Fourier Transform Infra-Red (FTIR), while anatomical characterization was carried out by calculating the fiber length and diameter, lumen diameter, fiber derivative values, and wall thickness using a microscope connected to a digital camera. Scanning Electron Microscope (SEM) pictures were taken in different magnifications. The results showed that sago frond contains 31.6% α-cellulose and 38% lignin. The α-cellulose content was within the standard range for non-timber forest products, but the lignin content had a relatively high value. Based on the derived value, namely class II, sago frond can be used as pulp and paper raw materials but needs pretreatment for the delignification process.

Keywords: Sago Palm (*Metroxylon sagu* Rottb.), Anatomical Characteristic, Chemical Content, FTIR

KANDUNGAN KIMIA DAN KARAKTERISTIK ANATOMI PELEPAH SAGU (*Metroxylon sagu* Rottb.) DARI KALIMANTAN SELATAN. Penelitian ini bertujuan untuk menganalisis kesesuaian limbah tanaman sagu (pelepah sagu) sebagai bahan baku pulp dan kertas dilihat dari kandungan kimia pelepah sagu dan karakteristik anatominya. Analisis kimia menggunakan serbuk pelepah dengan ukuran 40 - 60 mesh. Kandungan kimia berupa ekstraktif, lignin, holoselulosa, α -Selulosa, dan hemiselulosa dianalisis dan juga analisis menggunakan Fourier Transform Infra-Red (FTIR). Karakteristik anatomi dilakukan dengan melakukan penghitungan panjang dan diameter serat, diameter lumen, dan tebal dinding sel menggunakan mikroskop yang terhubung dengan kamera digital dan selanjutnya dilakukan perhitungan nilai turunan seratnya. Pengambilan gambar menggunakan *Scanning Electron Microscop* (SEM) juga dilakukan dengan beberapa perbesaran yang berbeda. Dari penelitian diperoleh data bahwa kadar ∝-selulosa pelepah sagu sebesar 31,585% dengan kandungan lignin 37,996%. Kandungan ∝ -selulosa pelepah sagu menunjukkan nilai standar pada produk hasil hutan bukan kayu namun kadar ligninnya menunjukkan nilai yang relatif tinggi. Dari nilai turunan serat pelepah sagu termasuk kelas II sehingga memiliki kesesuaian untuk bahan baku pulp dan kertas namun perlu perlakuan awal untuk proses delignifikasi.

Kata kunci: Sagu (*Metroxylon sagu* Rottb.), karakteristik anatomi, kandungan kimia, FTIR

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IX. INTRODUCTION

Sago plants (*Metroxylon sagu* Rottb.) are classified as abundant non-timber forest products in Kalimantan, where they grow in swamps and along river banks. In 2022, the plantation area in South Kalimantan was 7,857 ha, with a total production of 4,511 tons ha^{-1} (Saputra, Kissinger, & Itta, 2022). The Sago plant has tall stems with a wide diameter. During its processing to obtain flour, some wastes are often produced from the parts which have not been optimally used, namely the frond and bark. The remaining part is a source of cellulose, which can be used as a raw material for the pulp and paper industry.

Fiber sources as raw materials for pulp can be divided into two groups, namely wood and non-wood types. In Indonesia, the pulp industry often obtains its raw materials from broadleaf wood. The fibers produced by these species are relatively short, with a range of 0.76-2.9 mm (El-Sayed, El-Sakhawy, & El-Sakhawy, 2020). Short fibers often produce a homogeneous and perfectly mixed pulp; hence, they can be used to manufacture paper with a smooth surface, high opacity, improved printing quality, and high flexibility. However, these papers have low strength, specifically in their tear and tensile indexes (Fiserova, Gigac, & Balbercak, 2009; Yahya et al., 2019). Adding long fibers to the pulp mixture is necessary to increase the paper's strength. Long fibers can be obtained from needle-leaf wood and non-timber forest products, such as frond, bagasse, bamboo, jute, straw, and agricultural waste.

Sago frond and bark are abundant sources of cellulose in South Kalimantan. Several studies were also carried out on the wastes, such as the application of the frond as an alternative adsorbent material and charcoal (Wahi, Chuah, Ngaini, Nourouzi, & Choong, 2014; Johan, Ahmed, Omar, & Hasbullah, 2021), but none explored its usage as an alternative mixture for raw materials in the pulp and paper industry and particle board. The major component of sago frond is crude fiber and carbohydrates, with a value of 17.90%-34.44% and 51.44%-72.87%, respectively (Marvie & Sunarti, 2021). Therefore, an analysis of its chemical content and anatomical characteristics as a source for pulp and paper raw materials and particle board was carried out in this study. The use of the waste can increase their value and improve the quality.

Commented [A1]: This sentence seems to be incomplete. Please elaborate more on what quality will be increase with the use of waste in this sentence.

X. MATERIAL AND METHOD

A. *Materials*

The material used for this research was frond of sago (*M. sagu Rottb.*), acetic acid (CH_3COOH), sulfuric acid (H_2SO_4), benzene (C_6H_6), nitrite acid (HNO_3), acetone (CH_3COH_3), ethanol (C_2H_5OH), 1% and 17,5% of natrium hydroxide, distilled water, xylol, and safranin. The equipment used in this study was an electric microscope, desiccator, water bath, hot plate stirrer, oven, electronic balancing, hammer mill, 40 and 60 mesh sieve, magnetic stirrer, beaker glass, erlenmeyer, object and cover glass.

B. *Procedure:*

The sago frond waste was collected from Sungai Tabuk village, Banjar Regency, South Kalimantan, Indonesia. About 2 m of sago frond from the base were collected. It was produced in the form of chips with a size of 3 cm × 3 cm × 2 mm and then powdered. The chemical analysis and Fourier Transform Infra-Red (FTIR) (Shimadzu FTIR Prestige-21) were carried out using powder with a size of 40 - 60 mesh. The sample was placed in an FTIR spectrometer, and then the FTIR instrument sends infrared radiation of about 10.000 to 100 cm^{-1} through a sample, with some radiation absorbed and some passed through. The absorbed radiation is converted into

vibrational energy. The resulting signal at the detector presents as a spectrum representing a molecular fingerprint of the sample. Each chemical structure will produce a unique spectral fingerprint; thus, the chemical structure can be identified. Furthermore, the sample used for the measurement of fiber dimensions was in the form of a stick, which was macerated using the Schultze method. The softened sample was stained with safranin and washed in alcohol with a graded concentration, followed by immersion in xylol.

Moisture Content

The sample was weighed and placed in a weighing bottle with a known weight. It was then dried in an oven at 103 ± 2°C for 12 hours until it was constant. Moisture content (MC) was then calculated using the formula (1):

$$MC = \frac{Innitial\ mass - Oven\ dry\ mass}{Oven\ dry\ mass} \times 100\% \quad \text{.....(1)}$$

Determination of Chemical Components

k. Extractive Content in Ethanol – Benzene

To determine the amount of organic solvent extract, a 2.5 g sample was extracted with a 120 mL mixture of 95% ethanol and benzene (1 : 2, v : v) for 6 hours using a Soxhlet extractor. The extractive content dissolved in benzene ethanol was calculated using standard methods (JWRS, 2000).

l. Lignin Content

The lignin content was obtained from the extractive-free samples, which were placed in a beaker. Subsequently, 30 mL of 98% H_2SO_4 was added and the mixture was kept at room temperature for one day. The solution was then boiled at 100°C for 60 minutes while the filtrate was washed until the smell of sulfuric acid disappeared. The samples were dried in an oven at 103 ± 2°C to obtain a constant weight. The residue obtained from the extraction was the lignin content.

m. Holocellulose Content

A total of 1 g of the extractive-free sample was weighed and placed into a 100 ml Erlenmeyer flask. Its moisture content was then measured and used to calculate the holocellulose content. Furthermore, 40 ml of distilled water, 1.5 ml of 25% $NaClO_2$ (sodium chlorite), and 0.125 ml of 100% glacial acetic acid were added to the sample. The mixture was stirred, and the Erlenmeyer flask was tightly closed, followed by heating in a water bath for 60 minutes at 80°C. It was then cooled in an ice bath and filtered using a weighed 1G3 filter glass. A total of 10 ml sample was added, followed by 25 ml of acetone. It was then dried in an oven at 103 ± 2°C for 1 day, after which it was cooled in a desiccator for 30 minutes and weighed.

n. α-Cellulose Content

The test of α-cellulose content in sago frond and bark was carried out in different steps. An empty 1G3 funnel filter was dried in an oven at 103 ± 2°C, cooled in a desiccator for 30 minutes, and the oven-dry weight was measured. A total of 0.5 g of the holocellulose sample was weighed and placed in a ± 20 mL wide-mouth vial. Subsequently, 6.25 ml of 17% NaOH was added, followed by stirring using a magnetic stirrer for 15 minutes. The mixture was then left for 30 minutes, and 8.25 ml of 17% NaOH was added. It was stirred using a magnetic stirrer for 5 minutes and left for 60 minutes. The final mixture was then filtered using a IG3 filter glass, followed by rinsing with 25 ml of 8.3% NaOH and 100 ml of distilled water. The hose attached to the vacuum

bottle was removed, and the sample in IG3 was placed in 10 ml of 10% acetic acid for 3 minutes. Subsequently, the hose was reconnected and left until the entire solution was sucked out. The sample was then rinsed with distilled water until it became neutral, as indicated by the blue litmus paper attached. It was dried in an oven at 103 ± 2°C for 24 hours, removed, cooled in a desiccator for 30 minutes, and weighed.

o. Hemicellulose Content

The hemicellulose content was calculated by subtracting the holocellulose content from α-cellulose.

Measurement of Fiber Dimension and Derived Fiber

Small sticks of sago frond were collected and macerated with Schulz's solution as preparation to determine sago fiber anatomical properties. Fiber dimensions of fifty fibers were measured under an electronic microscope and used to determine fiber properties. Runkel Ratio, Slenderness Ratio, Muhlsteph's Ratio, Coefficient of Rigidity), and Flexibility Ratio were calculated by the following equation (Istikowati el al., 2016a):

$$Runkel\ Ratio = \frac{Fiber\ wall\ thickness \times 2}{Fiber\ lumen\ diameter} \quad \ldots\ldots (2)$$

$$Slenderness\ Ratio = \frac{Fiber\ length}{Fiber\ diameter} \quad \ldots\ldots (3)$$

$$Muhlsteph's\ Ratio = \frac{(fiber\ diameter)^2 - (fiber\ lumen\ diameter)^2}{(fiber\ diameter)^2} \quad \ldots\ldots (4)$$

$$Coefficient\ of\ Rigidity = \frac{Fiber\ wall\ tickness}{Fiber\ diameter} \quad \ldots\ldots (5)$$

$$Flexilility\ coefficient = \frac{Fiber\ Lumen\ diameter}{Fiber\ diameter} \quad \ldots\ldots (6)$$

The Scanning Electron Microscope figures frond were then taken in different magnifications.

XI. RESULT AND DISCUSSION

The chemical content analysis results of the sago frond showed the moisture (%), ethanol-benzene extractive (%), lignin (%), acid-soluble lignin (%), holocellulose (%), and ∝-cellulose (%) content as well as the FTIR.

A. Chemical content analysis

The results showed that the moisture content (MC) of the sago frond was 75.434%. The value obtained can vary in different areas with the same plant species. Moisture content can also be affected by the dryness of the sample when it is powdered before baking. Water is needed by plants to transport nutrients and minerals. Determination of MC in the pulp and paper industry is often used to calculate the use of cooking chemicals in the pulping process.

The ethanol-benzene extractive content of the sago frond was 5.56% (Table 1), which was lower compared to that of Purun Tikus *(Eleocharis dulcis)* extract, namely 9.53%. High value of ethanol-benzene extractive in pulp raw materials is not expected because it causes difficulty in the breakdown of fiber during the cooking process (Sunardi & Istikowati, 2012). The low extractive content of sago frond makes it suitable as a pulp and paper raw material and fiber-based product

Commented [A2]: Please rewrite this sentence. Or is it okay if this sentence is changed to "Moisture content can also be affected by the dryness degree of the powdered sample before it is dried using the oven"?

such as fiber biocomposite. It is because extractive substances can cause pitch, namely spots on the paper produced, and the tools used can easily be dull. High levels can also inhibit the entry of chemicals during the pulp ripening process (Sugesty, Kardiansyah, & Pratiwi, 2015; Istikowati et al., 2016b).

Table 1 Chemical content of non-wood materials

Parameters	Chemical content (%)				
	Sago frond	Purun Tikus[1]	Pandan Rasau[2]	Salacca frond[3]	Nipa frond[4]
Moisture content	75.43	92.68	96.07	-	-
Extractive content	5.56	9.53	4.60	7.8	1.9
Lignin content	37.99	26.40	31.67	23	17,8
Holocellulosa	55.63	-	58.73	57.6	61,6
α-Cellulosa	31.59	-	27.06	29.3	35,1
Hemicellulose	24.05	-	31.67	28.3	26,4

Notes: [1] Sunardi & Istikowati (2012); [2] Herlina et al. (2019); [3] Hakim et al. (2021); [4] Tamunaidu & Saka (2011)

Commented [A3]: Please add the scientific name for Pandan Rasay, Purun Tikus, Salacca, and Nipa

Furthermore, the lignin content of sago frond was 37.99% (Table 1), which was higher than Pandan Rasau and almost the same as reeds lignin, namely 31.67% and 31.29%, respectively. The value obtained was also higher compared to woods widely used as raw material for pulp and paper, namely *Acacia mangium*, *Falcataria moluccana*, and *Eucalyptus urophylla* with content of 31.30%, 23.77%, and 24.31%, respectively (Karlinasari, Nawawi, & Widyani, 2010; Yahya et al., 2019; Nasdy, 2013). Sago frond lignin content can be categorized as high, which is not needed in the industry because it can increase the need for cooking chemicals, thereby making it less economical (Putra, Wardenaar, & Hasni, 2018). Lignin is a component that must be removed in the pulping process, making the wood cells break down easily into single fibers. Its presence in the pulp can inhibit hydrogen bonding, cause an adverse effect on color, and increase the stiffness of the paper sheets (Sugesty et al., 2015). Material with low lignin content is more desirable for pulpwood because the content affects pulp yield as well as the bleaching process, with higher content of lignin in wood leading to lower pulp yield and paper strength (Istikowati et al., 2016b).

High holocellulose and α-cellulose content are needed in the manufacture of pulp because it increases the yield (Yahya et al., 2019). The value of holocellulose and α-cellulose obtained for sago fronds in this study was 55.63% and 31.59%, respectively. Cellulose-based materials with high holocellulose content are good for pulp and paper because they help to increase the yields during the pulping process.

Hemicellulose acts as a binder to the paper-forming fibers; hence, a sufficient amount helps to produce quality papers (Yahya et al., 2019). The pulp yield and physical properties of the sheet produced are often affected by the hemicellulose content. However, very high levels are not suitable for the pulping process because the time and power required for milling and separating the fibers during mechanical treatment also increase (Sugesty et al., 2015).

B. Fourier Transform Infra-Red (FTIR)

FTIR is a spectrum measurement technique based on the material's response to electromagnetic radiation. It is often used for qualitative and quantitative analysis to determine the groups of organic and inorganic compounds in a sample. The measurement can also be used to determine the molecular structure of a compound. The results of the FTIR wave spectrum on the extractive-free sago frond are presented in Figure 1.

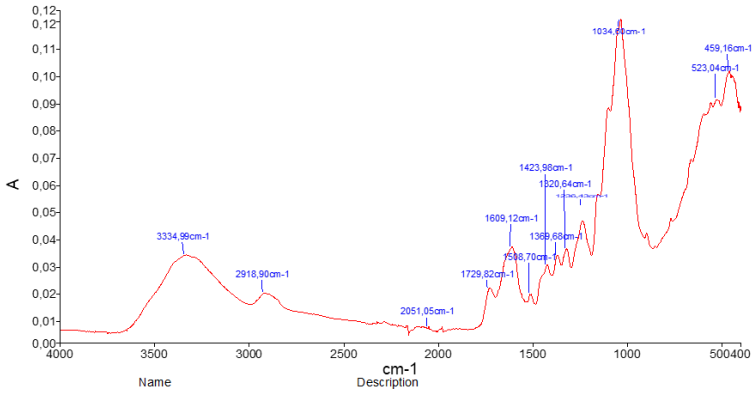


Fig. 1. FTIR spectrum of sago frond

Functional group analysis was carried out to determine the holocellulose, α-cellulose, hemicellulose, and lignin content of the sample. Furthermore, the groups in organic compounds can absorb electromagnetic radiation at wavelengths of 2.5-25 m or wave numbers of 400-4000 cm^{-1} (Sutiya, Istikowati, & Rahmadi, 2012). The data of the IR spectrum wave and its interpretation are presented in Tables 2 and Table 3, respectively.

The O-H functional group is the cellulose hydroxyl obtained from the spectrum of the sample, as shown in Table 3. The C=C group extends the aromatic ring (lignin) to the sago frond. The wave number for the C-H bonding of cellulose, hemicellulose, and pectin was 459.16 cm^{-1}.

FTIR presents qualitative data in the form of a spectrum that shows peaks or wave numbers. The wave numbers, which were interpreted into functional groups and chemical bonds, are used to determine the chemical content of a material. The spectrum of the sago frond shows its lignin, hemicellulose, and cellulose content. The extractive wave value does not appear in the FTIR test because it uses an extractive-free sample. The results are in line with the chemical component tests that sago frond contains 37.99% lignin, 55.63% holocellulose, 24.05% hemicellulose, and 31.59% α-cellulose.

Table 2. Wave spectrum of sago frond

No.	Wave number (cm^{-1})	Functional group
1.	3,300	O-H
2.	3,400	N-H
3.	<3,000	C-H sp^3
4.	>3,000	C-H sp^2
5.	3,300	C-H sp
6.	2,850 & 2,750	C-H aldehyde
7.	2,250	C=N
8.	2,100	C=C
9.	1,300-1,000	C-O
10.	800-600	C-Cl
11.	~1,460	CH_2 bending
12.	~1,380	CH_3 bending

Table 3. Interpretation of infra-red wave spectrum

Spectrum of sago frond	Note
3,334.99	Shows the O-H functional group of the hydroxyl group (α-cellulose)
2,918.90	Shows C-H from the metal group
2,051.05	C=C Aromatic ring group (lignin)
1,729.82	C=O Acelyt group, carboxylic acid (hemicellulose)
1,609.12	C=C Aromatic ring group (lignin)
1,508.70	C=C Aromatic ring group (lignin)
1,423.98	C-H deformation (lignin, hemicellulose)
1,369.68	C-H vibration (α-cellulose)
1,320.64	C-H vibration (α-cellulose)
2,361.43	-
1,034.60	Shows C-O vibration from β-1,4-glycoside bonding (α-cellulose)
523.04	C-H deformation (lignin, hemicellulose, pectin)
459.16	C-H deformation (lignin, hemicellulose, pectin)

C. Anatomical Characteristics

Dimensions of the sago frond measured include fiber length and diameter, lumen diameter, as well as cell wall thickness. The results of the average measurement of fiber dimensions were used to obtain its derivative value, and they have a positive correlation. The measured derivative values include the Runkel ratio, slenderness, muhsteph ratio, coefficient of rigidity (stiffness), and flexibility ratio. The results of the dimension measurement of the sago bark and frond fiber are presented in Table 4.

Table 4. Fiber dimension of non-wood materials

Type	Fiber dimension			
	Fiber length (mm)	Fiber diameter (µm)	Lumen diameter (µm)	Fiber wall thickness (µm)
Sago frond	2.11	12.77	5.92	3.61
Pandan rasau[1]	1.56	11.10	6.80	2.50
Purun tikus[2]	1.68	5.89	2.68	1.61
Palm oil[3]	1.07	28.15	22.57	2.79

Notes: [1] Herlina et al. (2019); [2] Sunardi & Istikowati (2012); [3] Yahya et al. (2019)

Sago frond is a lignocellulosic natural fiber with a long length, and it is longer than Pandan Rasau and Purun Rat, while it has almost the same length as reed fibers. Long fibers often have stronger bonds, and they are not easily separated. Furthermore, the folding strength of the paper was high, and it was not easy to tear. Excessively long fibers can lead to the production of rough paper. Hence, it is important to reduce the length to increase the smoothness of the product.

The diameter of the sago frond fiber was 12.77 µm, and it was classified as slender. It indicates that the sample is suitable for pulp because it can produce thinner and stronger paper (Sunardi & Istikowati, 2012). The slender fibers are easily interwoven and form sheets of paper with good properties, which are not easily torn.

The lumen diameter of the sago frond was 12.77 µm, and this value is higher than Purun Rat and bamboo Betung but lower compared to reeds. The fibers also have thinner cell walls compared to reeds and bamboo betung. Thin walls are easily flattened, providing a large surface area for bonding between fibers. This condition causes low tear values but high folding, breaking, and tensile strengths (Yahya et al., 2019).

D. Derived Wood Properties

Derived wood properties were obtained by comparing the results of the dimension measurements. Derived wood was used to predict the quality of the pulp to be produced. Moreover, the derived values of sago bark and frond are presented in Table 5. The requirements and value of wood fiber as raw material for pulp and paper are shown in Table 6. The average fiber length of sago frond fibers is 2.11 mm, which can be categorized as class II. The fiber length of the sago frond is almost similar to reed and longer than Pandan Rasau and Purun Tikus, as shown in Table 4. The length of fiber produce paper with high strength quality.

Table 5. Derived wood properties of non-wood fiber

Derived wood	Sago frond	Pandan rasau[1]	Purun tikus[2]
Runkel ratio	1.30	0.72	1.20
Slenderness ratio	164.50	140.54	285.45
Muhsteph ratio (%)	81.24	166.46	38.40
Coefficient of rigidity	0.28	0.2	0.27
Flexibility ratio	0.43	0.61	0.45

Notes: [1] Herlina et al. (2019); [2] Sunardi & Istikowati (2012)

Table 6. Standard of derived wood properties (Silitonga, 1972)

	Class I		Class II		Class III		Class IV	
	Require-ment	Score	Require-ment	Score	Require-ment	Score	Require-ment	Score
Fiber length (mm)	2.2	100	1.6-2.2	75	0.9-1.6	50	<0.9	25
Runkel ratio	<0.25	100	0.25-0.5	75	0.5-1.0	50	>1.00	25
Mulhstep ratio (%)	<30	100	30-60	75	60-80	50	>80	25
Slenderness ratio	>90	100	70-90	75	40-70	50	<40	25
Flexibility ratio	>0.80	100	0.6-0.8	75	0.4-0.6	50	<0.40	25
Stiffness ratio	<0.1	100	0.1-0.15	75	0.15-0.2	50	>0.20	25
Total		600		450		300		150
Score requirement	451-600		301-450		151-300		150	

Commented [A4]: Not found in reference

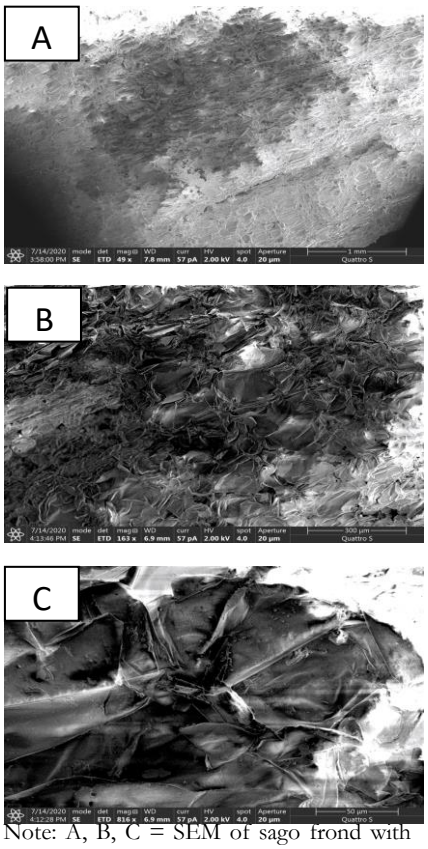
The Runkel ratio of sago frond was 1.30, and it can be categorized as class IV. A small ratio is important during the manufacturing process because it produces paper with strong fiber bonds and flat sheets, while a high value reduces flexibility and produces stiff paper (Istikowati et al., 2016b).

The slenderness ratio of the sago frond was 164.50; hence, it can be categorized as class 1. The value obtained was higher than pandan rasau, purun tikus, and reed fibers. Sago frond has a long fiber, which makes the weaving power and bonding very strong. Furthermore, a high value is related to the smoothness of the paper produced. High weaving power has a good influence on the tensile strength and breakage of paper or filler in biocomposites (Sugesty et al., 2015).

The Muhsteph ratio of sago frond was 81.24%, and it was categorized as class III. Paper produced from a high ratio has a rough surface, low squeezing strength, and is not plastic. Based on the value obtained, the fibers are not suitable for writing paper, but they can be used to produce wrapping or art paper. The coefficient of rigidity was 0.28, and it was categorized in class IV. The magnitude of this value is related to the stiffness of the paper produced. The higher the coefficient of rigidity, the higher the stiffness. The paper produced from these fibers is expected to have low tensile strength.

The flexibility ratio obtained was 0.43, and it was categorized in class III. A high ratio can produce papers that are more flexible and less stiff. The overall value of sago frond fiber derivatives was 325, and it was categorized in class II. Based on their properties, they can be used as an alternative raw material for pulp and paper.

The observation under SEM at high magnifications showed the 3D structure of the sago frond in different magnifications. Morphological characterization of the sago frond using SEM aims to observe the surface roughness. Based on the SEM photo obtained, the surface shows many cavities with thin cell walls (Figure 2). SEM images of the sago frond showed the cells of sago frond; however, it was not possible to differentiate between fiber and parenchyma.



Note: A, B, C = SEM of sago frond with magnification 30, 100, dan 500, respectively

Fig. 2. Scanning Electron Microscope (SEM) of sago frond

XII. CONCLUSION

The α -cellulose and lignin content of the sago frond were 31.59% and 37.99%, respectively. Furthermore, the amount of α -cellulose in the sample showed a standard value in non-timber forest products, but the lignin was relatively high. Based on the fiber derivatives, the sago palm was classified as class II. This indicates that it is suitable as pulp and paper raw and product-based fiber material but needs pretreatment for lignin removal.

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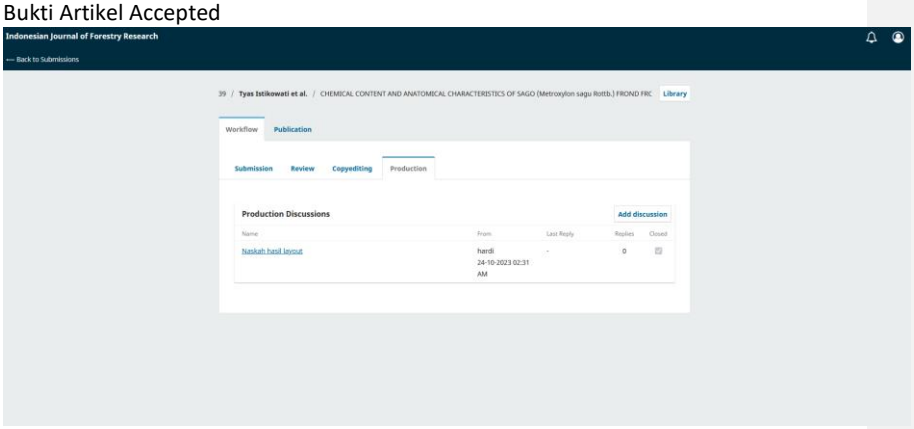

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The theoretical contribution made by the manuscript	Moderate
Does the manuscript draws on an appropriate range and depth of literature?	Yes
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Please check the lignin content in Table 1 (37.99%). With ……" Furthermore, the lignin content of sago frond was 42.02% (Table 1)….."
Which one is correct ?

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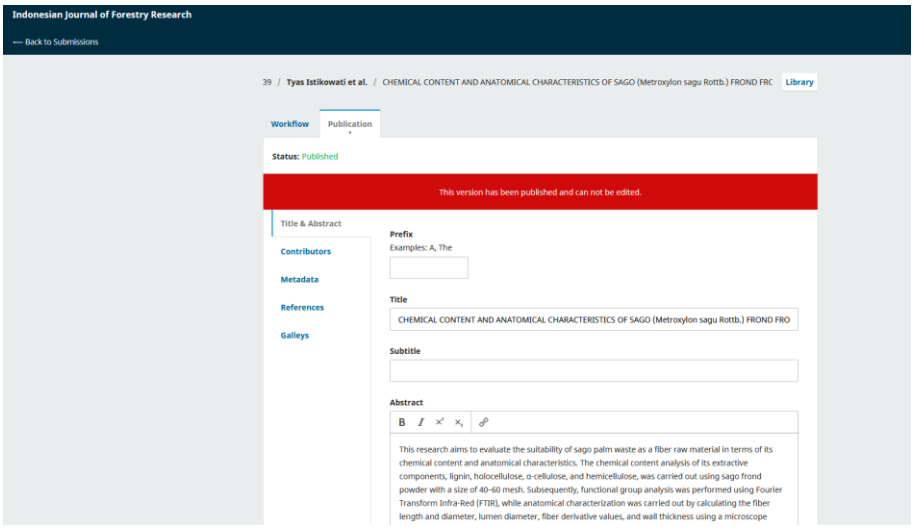

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA

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CHEMICAL CONTENT AND ANATOMICAL CHARACTERISTICS OF SAGO (*Metroxylon sagu* Rottb.) FROND FROM SOUTH KALIMANTAN, INDONESIA. This research aims to evaluate the suitability of sago palm waste as a fiber raw material in terms of its chemical content and anatomical characteristics. The chemical content analysis of its extractive components, lignin, holocellulose, α-cellulose, and hemicellulose, was carried out using sago frond powder with a size of 40–60 mesh. Subsequently, functional group analysis was performed using Fourier Transform Infra-Red (FTIR), while anatomical characterization was carried out by calculating the fiber length and diameter, lumen diameter, fiber derivative values, and wall thickness using a microscope connected to a digital camera. Scanning Electron Microscope (SEM) pictures were taken in different magnifications. The results showed that sago frond contains 31.6% α-cellulose and 38% lignin. The α-cellulose content was within the standard range for non-timber forest products, but the lignin content had a relatively high value. Based on the derived value, namely class II, sago frond can be used as pulp and paper raw materials.

Keywords: Sago palm, *Metroxylon sagu* Rottb., anatomical characteristic, chemical content, FTIR

KANDUNGAN KIMIA DAN KARAKTERISTIK ANATOMI PELEPAHSAGU (Metroxylon sagu *Rottb.) DARI KALIMANTAN SELATAN. Tujuan dari penelitian ini adalah untuk menganalisis kesesuaian limbah tanaman sagu (pelepah sagu) sebagai bahan baku pulp dan kertas berdasarkan kandungan kimia dan karakteristik anatominya. Serbuk pelepah bukuran 40–60 mesh digunakan dalam proses analisis kimia kayu. Kandungan kimia berupa ekstraktif, holoselulosa, α-Selulosa, dan hemiselulosa dan kadar lignin dianalisis dan selanjutnya dianalisis menggunakan Fourier Transform Infra-Red (FTIR). Penghitungan panjang dan diameter serat, diameter lumen, dan tebal dinding sel diukur untuk karakteristik anatomi selanjutnya perhitungan nilai turunan serat dihitung berdasar data yang didapat. Pengambilan gambar dengan beberapa perbesaran yang berbeda menggunakan Scanning Electron Microscop (SEM) dilakukan. Dari penelitian diperoleh data bahwa kadar α-selulosa dan kandungan lignin secara berurutan sebesar 31,585% dan 37,996%. Kadar ligninnya menunjukkan nilai yang relatif tinggi namun kandungan α-selulosa pelepah sagu menunjukkan nilai standar pada produk hasil hutan bukan kayu. Dari nilai turunan serat pelepah sagu tergolong kelas II sehingga dinilai memiliki kesesuaian untuk bahan baku pulp dan kertas.*

Kata kunci: Sagu, Metroxylon sagu *Rottb., karakteristik anatomi, kandungan kimia, FTIR*