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# Cassava Peels for Alternative Fibre in Pulp and Paper Industry: Chemical Properties and Morphology Characterization

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**Abstract:** Without a proper waste management, the organic wastes such as cassava peels could result in increased amount of solid waste dump into landfill. This study aims to use non-wood organic wastes as pulp for paper making industries; promoting the concept of 'from waste to wealth and recyclable material'. The objective of this study is to determine the potential of casssava peel as alternative fibre in pulp and paper based on its chemical properties and surface morphology characteristic. Quantified parameters involved are holocellulose, cellulose, hemicellulose, lignin, one percent of sodium hydroxide, hot water solubility and ash content. The chemical characterization was in accordance with relevant TAPPI Test, Kurscher-Hoffner and Chlorite methods. Scanning electron microscopy (SEM) was used to observe and determine the morphological characteristic of untreated cassava peels fibre. In order to propose the suitability of the studied plant as an alternative fibre resource in pulp and paper making, the obtained results are compared to other published literatures especially from wood sources. Results indicated that the amount of holocellulose contents in cassava peels (66%) is the lowest than of wood (70 - 80.5%) and canola straw (77.5%); however this value is still within the limit suitability to produce paper. The lignin content (7.52%) is the lowest than those of all wood species (19.9-26.22%). Finally, the SEM images showed that untreated cassava peel contains abundance fibre such as hemicellulose and cellulose that is hold by the lignin in it. In conclusion, chemical properties and morphological characteristics of cassava peel indicated that it is suitable to be used as an alternative fibre sources for pulp and paper making industry, especially in countries with limited wood resources.

**Keywords:** Cassava peel, chemical compositions, green technology, organic waste, sustainability

## 1. Introduction

Nowadays, rapid increase in population, accelerated urbanization and industrialization processes had caused depletion of wood resources as well as generated environmetal problems due to the disposal of industrial processing wastage. For instance, the amount of solid waste generated in Kuala Lumpur from 3,070 tons per day in 2000 to 3,478 tons per day in 2005 and is expected to increase even more in 2015 [1]. Besides, the organic waste is the major composition of solid waste that is generated in Kuala Lumpur rather than other solid wastes and it has increased from 1975 to 2000 is given in Table 1 [1].

Cassava (*Manihot esculenta Crantz*) peels are obtained from the processing of tuberous root of cassava industries [2]. Cassava peels is 1 ± 4 mm thick and may accounts 10 to 13% of the total dry matter of the cassava root [2,3]. In Malaysia, with large area of plantation of cassava with approximation of 2,769 ha in 2010, has produced large quantities of cassava during harvesting with annual production at approximately 37,187 tons [4]. The explosive development of plantation in this country has generated large amounts of cassava peels in which could inevitably create great environmental problems [5].

In 2005, Malaysia has a total production of pulp over 1 million tons per year where it was obtained from mature pulp wood [6]. The increased demands for paper consumption from virgin pulp have resulted in resources depletion, massive deforestation and environmental concerns due to the population growth. Therefore, to promote the concept of sustainability, cassava wastes are suggested as alternative fibre for pulp and paper production, and in the long run could greatly reduce the issues with environmental problems as wood consumption has been significantly reduced. Although, in pulp and paper making, organic wastes have some

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weaknesses when compare to woods, however in light of the great shortage of wood fibre, cost-effectiveness and abundance of organic waste materials, organic wastes are proven to be reasonable candidates for pulp and paper production.

Table 1 Solid Waste Composition (%) in Kuala Lumpur from 1975 to 2000 [1].

| Composition of waste | 1975 | 1980 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Organic | 63.7 | 78.05 | 40.8 | 61.76 | 68.67 |
| Paper | 11.7 | 11.48 | 30.0 | 12.16 | 6.43 |
| Plastic | 7.0 | 0.57 | 9.8 | 5.27 | 11.45 |
| Glass | 2.5 | 0.57 | 3.0 | 5.27 | 1.41 |
| Metals | 6.4 | 3.16 | 4.6 | 6.89 | 2.71 |
| Textile | 1.3 | 3.16 | 2.5 | 2.84 | 1.50 |
| Wood | 6.5 | 2.58 | 3.2 | 0.00 | 0.70 |
| Others | 0.9 | 0.43 | 6.1 | 5.81 | 7.13 |

The chemical properties of cassava peels fibre for pulp and paper production have never been explored in the literature. Therefore, in this study the chemical properties and morphological characteristic of cassava peels were investigated to estimate the potential deployment of cassava peel fibres in pulp and paper production.

## 2. Material and Methods

### 2.1 Material

Cassava peels were collected from Salleh Food Industry, Parit Kemang, Batu Pahat, Johor. Cassava peels were cut into 2 - 5 cm and washed to eliminate sand and other contaminants. Air-dried samples were grounded to 0.40 to 0.45 mm and stored in tight containers for further chemical and morphological analyses.

### 2.2 Chemical characterization

Chemical compositions of cassava peel were performed according to Technical Association of the Pulp and Paper Industry (TAPPI) Test Method. The samples were placed into soxhlet extraction for 6 hours according to method T 264 om-88. The evaluation of extractive substances was carried out in different liquids according to common standards, namely: hot water solubility (T 207 cm-08) and 1% sodium hydroxide solution (T 212 om-07). The ash content (T 211 om-07) also was quantified to determine the inorganic material in this sample. The amount of lignin, holocellulose, hemicelluloses and cellulose were assessed by using the following respective standard methods: T 222 om-06, Chlorination and Kurschner-Hoffner Methods. Experiments were conducted in triplicates.

### 2.3 Morphology characterization

The surface morphology of the cassava peel was visualized in a JEOL JSM-6380LA analytical Scanning Electron Microscope (SEM). The grounded sample (one-quarted spatula) was sprinkled and coated with a thin layer of gold-palladium film followed by the visual analysis under the SEM.

## 3. Results and Discussion

### 3.1 Chemical characterization

The chemical characterizations of cassava peels were determined and the results are summarized in Table 2. Results indicated that the cassava peels are characterized by relatively high amount of holocellulose (66%) and extractives, especially in 1% sodium hydroxide solubility (27.5%) and lower value of lignin (7.5%), hot water solubility (7.6%) and ash content (4.5%). The celluloses content (37.9%) are quite similar with hemicelluoses content (37%) obtained in cassava peels.In general, the high content of holocellulose, cellulose and hemicelluloses and lower content of lignin from cassava pees are acceptable for papermaking application [5].

The holocellulose content of cassava peel was found to be 66%, which was lower than that of Canola straw (77.5%) and wood sources (70-80.5%). Holocellulose is the total combination of cellulose and hemicelluloses content in oven dry plants [7]. High holocellulose content is considered advantageous for the pulp and paper industry because it could produce high pulp yield after cooking process [8]. Commonly, cellulose is the most basic and important constituent of paper and the quantity of cellulose in the main consideration in the paper making process where the paper strength properties depends on the cellulose content of raw material. Referring to Table 2, although cassava peels contain lower cellulose (37.9%) than wood materials; pine pinaster (55.9%) and eucalyptus globules (53%), however it is higher than the canola straw (36.6%) which has been proven to be a successful pulp for paper making [16,18]. According to Shakles [8], plant materials that contained 34% and higher cellulose content were characterized as promising candidate for pulp and paper manufacture from chemical composition point of view. Therefore, higher amount of cellulose content indicated that the high amount of pulp yield will be produced after chemical pulping process [9]. However, cassava peels are higher in hemicelluloses than wood sources (13.7 - 27.7%) but lower than canola straw (40.9%) as shown in Table 2 which could contribute to the strength of paper pulp.

Lignin is the component in plant structure that binds the cellulose fibres together. Prior to paper making process, the lignin must be removed from the pulp because it affects the performance and decrease the paper quality [10,11]. Based on Table 2, the lignin content was found lowest in cassava peel than canola straw and wood fibre (19.9 - 26.2%).

Lignin is considered to be an undesirable polymer that must be removed during pulping process [12]. In addition, lower lignin content could be advantageous as less amount of chemical during pulping and bleaching process [13] are needed and ultimately reducing hazard release to the environment.

Table 2 Chemical composition of cassava peels – comparison with other organic wastes and wood source plants (%, w/w oven dried materials)

| Materials / Components | Organic waste | | Wood | |
|---|---|---|---|---|
| | Cassava peels [Presentstudy] | Canola straw [16] | Pine pinaster[19] | Eucalyptus globules [19] |
| Holocellullose | 66.0 | 77.5 | 70.0 | 80.5 |
| Cellulose | 37.9 | 36.6 | 55.9 | 53 |
| Hemicellulose | 37.0 | 40.9 | 13.7 | 27.7 |
| Lignin | 7.5 | 20.0 | 26.2 | 19.9 |
| 1% NaOH | 27.5 | n.a | 7.9 | 12.4 |
| Hot water | 7.6 | n.a | 2.0 | 2.8 |
| Ash | 4.5 | 6.6 | 0.5 | 0.6 |

Ash is an inorganic material and also defined as the mineral component of lignocellulosic material that is found in plant fibres [8,14]. The ash content of cassava peel was found to be 4.5%. The ash content of cassava peel was markedly higher than that of the wood fibre (0.5 - 0.6%) but still lower than canola straw [6.6%] as shown in Table 2.

Water solubility content in the raw materials consist of sugar, colouring matter, starch and protein which could affect the pulping process [12,15]. As shown in Table 2, cassava peel contained higher amount of hot water than wood fibres. High content of hot water will generate low pulp content and vice versa after pulping process. Besides, cassava peel also show the higher amount of one percent sodium hydroxide solubility rather than wood fibres. This high value can be considered a drawback to the use of this material for pulping process. The consequence of such high solubility will indicate low pulp yield, especially from chemical pulping [16]. Therefore, from the content of 1% NaOH of cassava peel it can be expected to generate a lower yield pulp than pine pinaster and eucalyptus globulus.

From the chemical composition perspective, cassava wastes contained acceptable amounts of holocellulose, cellulose, hemicelluloses and lignin contents as an alternative fibre in pulp and paper making industries from non-wood resources.

## 3.2 Morpohology characterization

Changes in physical properties can be due to differences in fibre morphology which can be observed under different levels of magnifications to show major character of the fibre physical structure [7]. Fig. 1 displays the scanning electron microscopy of cassava peel observed under difference magnifications. The surface morphology of cassava peel is depicted in Fig. 1(a) which shows low pore size of structure because of the predominance structure of the micro pores.

In their natural state and before chemical extraction, fibre surface have encrusting substances such as hemicelluloses, lignin and pectin that form a thick layer to protect the important substances, such as the cellulose inside [7]. The presence of encrusting substance causes the fibre to have an irregular appearance as shown in Fig. 1(a). Besides, the white colour that is shown in Figure 1(b) indicates the presence of impurities on the surface of cassava peels due to the untreated material however, before the pulping process this material will be pretreated with alkaline solution [17].

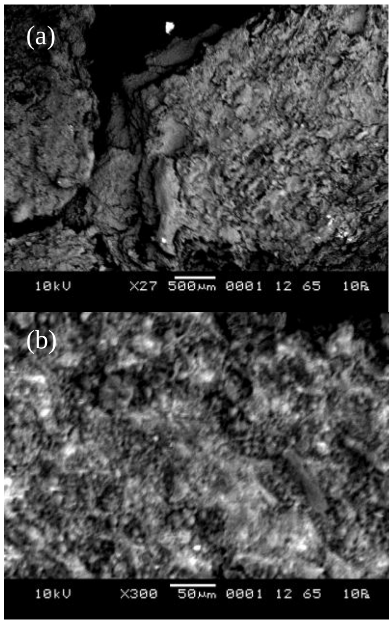


Fig.1 Scanning electron microscopy of cassava peel; a) and b) surface morphology of untreated cassava peel at x27 and x300 respectively

## 4. Conclusion

The cassava peel is one of the organic wastes that is a potential substitutes for conventional wood resources in pulp and paper making. The results from the chemical characterizations indicated that the cassava peels contain lower amount of the holocellulose and cellulose, but higher in the hemicellulose content. The lignin content is lower that canola straw (non-wood), however is somewhat higher than other wood resources. Moreover, higher amount of extractives such as 1% NaOH and hot water solubility in cassava peels indicated that the lower pulp yield will be produced during the pulping process. Morphology study of grounded cassava peels showed the presence of the hard surface and impurities.. In conclusion, cassava peels contain comparable amount of important pulp parameters and could be suitable as an alternative fibre for pulp and papermaking industries, which could promote the use of recyclable materials and in the long run, reduce the environmental issues.

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