PHYSICAL AND MECHANICAL PROPERTIES OF ARTOCARPUS INTEGER PEEL PAPER

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Abstract

There are some environmental problems that are faced when producing papers from trees such as deforestation, air pollution, greenhouse gas emissions and disposal of animal habitats. Jackfruit waste such as the peel could be used as a new raw material for producing papers and at the same time, it could reduce problems with waste disposal due to the peel being solid waste. The objectives of this research are to fabricate the *Artocarpus Integer peel* (*AIP*) paper and study its physical and mechanical properties. The basic weight of *AIP* paper is 80.76-85.30 g/m^2 and the bulk is 1.18-1.27 cm^3/g. The fabricated *AIP* paper shows that it has good folding, tearing index, tensile strength, strain, and tensile energy absorption. The porosity size of *AIP* paper is 31.58 µm. Thus, utilizing *AIP* as an alternative raw material could increase the economic value, help to reduce the cost of disposal and consequently reduce the environmental pollution.

Keyword: Artocarpus Integer peel, paper, physical properties, mechanical properties

Introduction

The paper industry had a production index of 114.7 in 2018. This shows an increase by 14.7 points compared to the base year which is in 2015 (Statista Research Department, 2019). Cellulose fiber is the main ingredient in paper (OrganoClick, 2019). The continuing high growth in paper consumption leads to an increasing demand for cellulose fiber which creates an additional pressure on Malaysia's diminishing forest resources.

Cempedak (*Artocarpus integer*), also called as "chempedak", is a tropical fruit from the Moraceae family (Singapore, 2019). This type of fruit will leave peel after consumption which is a nuisance to the environment since they are solid waste. With the increase in the production of processed fruit products, an abundant amount of *Artocarpus integer peel* (*AIP*) are disposed from food processing sector, causing a serious problem of disposal (Hasan, Nurul Adina Mohamed Razifuddin, Nurfatehah Wahyuny Che Jusoh, Rohayu Jusoh, & Herma Dina Setiabudi, 2018). Throughout 2017, *Artocarpus integer* produced in Malaysia is 26,935.16 Mt (Department of Agriculture, 2017). The huge amount of *Artocarpus integer* waste that are thrown away tend to bring about a serious waste disposal issue since the peel are solid waste and could create environmental problems such as pollution. *Artocarpus integer* waste also make the cost of waste disposal become increased. Besides, the cutting down of trees for paper-making process also brings about environmental issues such as deforestation, air pollution, greenhouse gas emissions and disposal of animal habitats. Thus, proper approaches to convert waste into valuable product such as a new raw material for papers are necessary and could contribute to the protection and sustenance of the environment. A research conducted by Sundarraj and Ranganathan (2017) revealed that *AIP* contains a high amount of cellulose (27.75 %), pectin (7.52 ± 0.12 %), protein (6.27 ± 0.03 %) and starch (4 %) (Sundarraj & Ranganathan, 2017). The cellulose content in *AIP* is higher than pomelo's (Citrus grandis) albedo peel (21.29% - cellulose) (Mat Zain, 2015), orange rind (13.6% - cellulose) (Ververis et al., 2007), lemon peel (12.7% - cellulose) (Ververis et al., 2007), and orange peel (11.93% - cellulose) (Sánchez Orozco et al., 2014). By using *AIP* in the paper-making process, it could reduce the problems of deforestation in the world. The objectives of this project are to fabricate paper using *AIP* and to determine its physical and mechanical properties.

Materials and Methods

The *Artocarpus Intiger* was obtained from a stall at Bandar Jengka Pusat, Pahang. Fresh *Artocarpus Intiger peel (AIP)* were cleaned with distilled water and sliced into the thickness of 5-10 mm. Next, the *AIP* spikes were removed. After that, *AIP* were dried in an oven for about 4 hours at 70 ˚C (**Figure 1**).

Figure 1 Dried *AIP*

Soda Pulping Process

The weight of Sodium Hydroxide (NaOH) was determined at 24 % from the weight of the oven-dried *AIP* (OD). *AIP* (OD) underwent NaOH treatment for 3 hours at the temperature of 170˚C in the M.K digester. Subsequently, the treated *AIP* (OD) were washed with distilled water and then screened. Next, the *AIP* were ground by using the standard disintegrate machine to reduce the size of the fiber. After that, water was filtered out from the *AIP* by using a spin dryer and left dried (**Figure 2**).

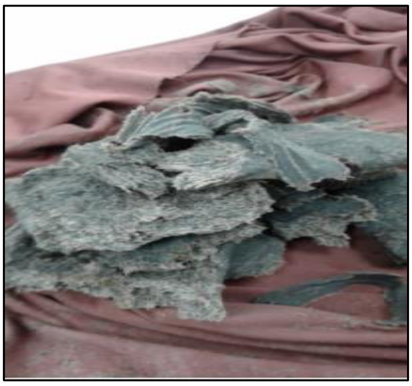

Figure 2 Dried *AIP* pulp

Screening Process

The screening process was done by using PTI Sommerville Fractionators according to TAPPI T 275 standard with the slot size of 0.15 mm. The oversized debris particles from *AIP* pulps were screened out. Finally, the pulps with the size of 200μ-250μ were screened out by a screening container to remove the water. The leftover pulps in the screener were considered as waste and they were kept in the oven to dry in order to get the exact mass of the pulps that were left to produce the paper.

Bleaching Process

The pulps were formed into small pieces and dampened with distilled water and then put in a plastic bag. 20% of NaOH and 30% of H_2O_2 were then mixed together in a beaker and poured into the plastic bag. The plastic bag then was soaked into a water bath for 30 minutes. For every 10 minutes, the plastic bag was untied to add some water and let some air out of it. After 30 minutes, the bleaching process was finished. The pulps were washed and finally, they were dried using the spinner in a washing machine.

Papermaking Process

The paper sheet former was filled with some water. It was then squeezed consistently with a press machine at 345 kPa for 5 minutes (**Figure 3**).

(a) (b)

Figure 3 (a) Squeezed AIP paper (b) AIP paper

Evaluation of paper sheets

The physical properties measured are the apparent density and bulk. The standard procedure of measuring the apparent density is TAPPI T 410. Apparent density is also known as "grammage" and it measures the weight of a paper per unit area and is expressed in grams per square meter. The standard procedure of measuring book bulk is laid out in TAPPI T 500.

$$\text{Bulk (cubic centimeter/g)} = \text{Thickness (mm)}* 1000/ \text{Basis Weight (g/m}^2\text{)}.$$

The mechanical properties of *AIP* paper were measured with several types of parameters through mechanical tests such as tensile test (MS ISO 1924-2 : 2008, IDT : Paper and Board – Determination of Tensile Properties – Part2 - Constant Rate of Elongation Method), tearing test (MS ISO 1974 : 1990, IDT : Paper – Determination of Tearing Resistance - Elmendorf Method), bursting strength (MS ISO 2758: 2001, IDT : Paper Determination of Bursting Strength) and folding test (MS ISO 5626 : 1993, IDT : Paper – Determination of Folding Endurance) (**Figure 4**). These measurements were repeated for commercial paper (Double A paper 80 gsm) for comparison. The porosity size was measured by using Metallurgical Microscope Olympus BX51M.

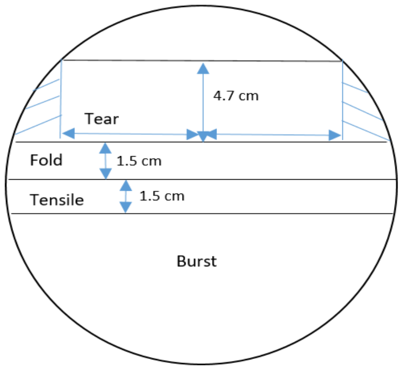

Figure 4 Portion of paper used for mechanical properties measurements

Result and Discussion

Physical properties

Basic weight

The basic weight of the *AIP* paper is 80.76-85.30 g/m^2. This value in range of the bond grade paper whereas between 60-90 g/m^2 (Goyal. H., 2012).

Bulk

Bulk is used to measure the ratio of paper thickness to its weight in cubic centimeters per gram (Dombrower, 2017). Bulk determines the suitability of a paper to the type of printers. The bulk of the *AIP* paper is 1.18-1.27 cm^3/g. This bulk value shows that *AIP* paper is similar to Bleached Kraft gred paper which is 1.20 cm^3/g (Goyal, 2012). The low value of bulk of the *AIP* paper indicates that the paper sheet is smooth, glossy and less opaque (Goyal, 2012).

Mechanical properties

The mechanical properties for each type of paper are tearing index, burst, folding, tensile strength, strain and tensile energy absorption (TEA). **Table 1** shows the mechanical properties of *AIP* paper.

Table 1 The mechanical properties comparison of the *AIP* paper, commercial paper, durian rind paper, and coir CMP paper (Rizal et al., 2015; Saad & Ibrahim, 2014).

Type of paper	Tearing Index (mNm^2/g)	Burst Index (kgf/cm^2)	Folding (count)	Tensile strength (MPa)	Strain (%)	Tensile energy absorption (TEA) (J/m2)
AIP paper	0.16698	2.65	9	2673	4.076	6.885
Commercial paper	0.35	2.00	8	1590	5.893	6.265
Durian rind paper (Rizal et al., 2015)	4.918	1.86	15	-	-	-
Coir CMP (Saad & Ibrahim, 2014)	7.050	1.85	8.07	-	-	-

Tearing index and Tensile Strength

Tearing index is defined as tearing strength divided by basis weight (Caulfield & Gunderson, 1988). Tearing index of *AIP* paper is 0.16698 mNm^2/g while commercial paper is higher which is 0.35 mNm^2/g. However, the tensile strength for AIP paper is higher by 68.11 % than commercial paper. According to Goyal (2012), tearing strength is inversely proportional to tensile strength. If a sheet has high tearing strength, its tensile strength will be low (Goyal, 2012). The tensile strength value can be used as a potential indicator of resistance to web breaking during printing or converting (Goyal, 2012). Higher tensile strength of *AIP* paper in comparison to commercial paper indicates that the *AIP* paper has better fiber strength, fiber bonding and fiber length (Goyal, 2012). The *AIP* paper also has the capability to be printed on as displayed in **Figure 5.**

Burst index

Burst index is obtained by dividing the bursting strength in kPa by the grammage of the paper in g/m^2 (Caulfield & Gunderson, 1988). Bursting factor needs to be determined to ascertain the bursting strength and quality of papers. The bursting strength of a paper material explains the amount of pressure that a material can tolerate before it ruptures. The bursting strength of a paper changes with the change in the weight of the paper. *AIP* paper has a higher burst factor (24.52%) compared to commercial paper. The advantage of having higher bursting factor is a high capability to accommodate a fragile product.

Folding endurance

Folding endurance is the capacity of a paper to keep up its elasticity when collapsed forward and backward under a pliable load (Prambauer et al., 2015). It measures the flexibility of the paper (Shetty, 2019). The count number of folding is important for printing grades where the paper is subjected to multiple folds like in books, maps or pamphlets. **Figure 6** shows the ability of *AIP* paper to be turned into a paper bag due to its high folding endurance. The folding endurance of the fabricated paper is 9 while the commercial and coir CMP papers are 8 and 8.07 respectively. The count number of *AIP* paper is higher than the commercial and coir CMP papers. According to Shetty (2019), long and flexible fibers provide high folding endurance.

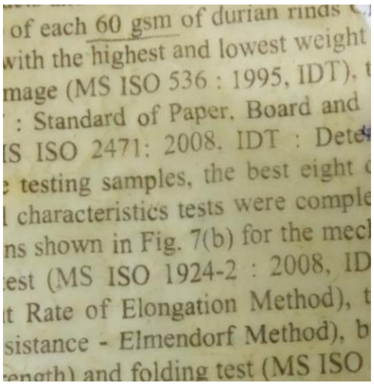

Figure 5 The printed *AIP* paper

Figure 6 Paper bag from *AIP* paper

Tensile energy absorption (TEA)

proves to be a significant property relating to durability. TEA is a measure of the ability of paper to absorb energy under variable loading conditions and can be used to gauge the durability of papers that are subjected to repetitive straining. TEA expresses the "toughness" of the sheet (Technical Association of the Pulp and Paper Industry, 2006). TEA of the fabricated paper is 9.9 % higher than the commercial paper. TEA value is very important in packaging applications such as multi-wall sacks, favorable drop tests and low failure rates

(Technical Association of the Pulp and Paper Industry, 2006).

Porosity

The porosity size is an important physical nature to declare the characteristic of the texture and the quality of materials (Cui et al., 2017). Porosity is an empty space between material and the small part of the empty volume space within the total volume (Astuti et al., 2018). The average porosity size for the fabricated paper is 31.58 µm. Determination of the flow rate of water through paper was using DIN 53137 procedure (Nagel, 1911). The flow rate of water through *AIP* paper is 0.69 mL/sec.

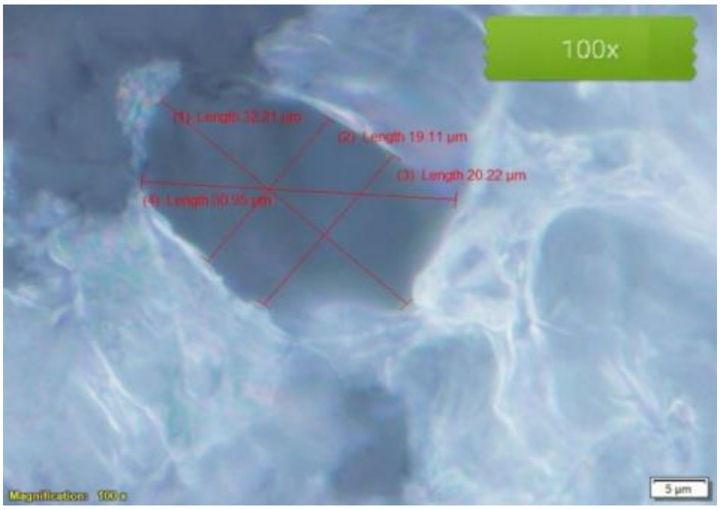

Figure 7 The porosity size of *AIP* paper measured by using Metallurgical Microscope Olympus BX51M

Conclusion

In conclusion, physical and mechanical properties of the AIP paper show a high potential to reduce the problem of deforestation through the use of *Artocarpus Intiger Peel* as a new resource for raw material. The value in the tearing index for *AIP* paper is 0.16698 mNm^2/g, 2.65 kgf/cm^2 for burst index, 9 counts for folding number, 2673 MPa for tensile strength, 4.067for strain and 6.885 J/m^2 for TEA. Comparison between *AIP* paper and other fabricated papers shows that the AIP paper has better burst index, tensile strength, and TEA but low tearing index. Hence, another study on *AIP* paper needs to be carried out for an improvement.

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Conflict of interests

The authors declare that there is no conflict of interests with any organization or financial bod y for supporting this research.

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