

Soda-Anthraquinone Durian (*Durio Zibethinus Murr.*) Rind Linerboard and Corrugated Medium Paper: A Preliminary Test

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Soda-Anthraquinone Durian (*Durio Zibethinus Murr.*) Rind Linerboard and Corrugated Medium Paper: A Preliminary Test

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Abstract. A preliminary test was conducted to investigate the characteristics of linerboard and corrugated medium paper made from durian rind waste. Naturally dried durian rinds were pulped according to Soda-Anthraquinone (Soda-AQ) pulping process with a condition of 20% active alkali, 0.1% AQ, 7:1 liquor to material ratio, 120 minutes cooking time and 170°C cooking temperature. The linerboard and corrugated medium paper with a basis weight of 120 gsm were prepared and evaluated according to Malaysian International Organization for Standardization (MS ISO) and Technical Association of the Pulp and Paper Industry (TAPPI). The results indicate that the characteristics of durian rind linerboard are comparable with other wood or non-wood based paper and current commercial paper. However, low CMT value for corrugated medium and water absorptiveness quality for linerboard could be improved in future. Based on the bulk density (0.672 g/cm³), burst index (3.12 kPa.m²/g) and RCT (2.00 N.m²/g), the durian rind has shown a good potential and suitable as an alternative raw material source for linerboard industry.

1. Introduction

Due to the rising global demand for fibrous material, a worldwide shortage of trees in many areas, and increasing environmental awareness, non-woods fibers have become one of the important alternative sources of fibrous material for the 21st century[1]. Finish Forest Industries, Europe and World [2] reports that global paper and board production of packaging paper was increased about 2.3% in 2014 compared to previous year. The Malaysian pulp and paper industry is heavily dependent on imported fiber, particularly virgin pulp, and is also facing the need to find a new source of fiber to strengthen [3]. The rich abundances of agricultural waste in Malaysia could be converted as a promising non-



wood based raw material for the packaging industry. Various non-wood based materials in Malaysia such as coconut coir, kenaf, pineapple leaves, coir, oil palm male flower spikes(OPMFS) [4,5] offers a good quality and potential to be utilized as raw material in the manufacturing of pulp and paper products for packaging industry.

Durian (*Durio Zibethinus Murray*) is a popular fruit in South East Asia region especially in Malaysia, Thailand, Indonesia and Filipina; and commonly called “King of Fruit”. Durian is among the popular fruit which are grown and consumed locally and exported in Malaysia [6]. According to Ministry of Agriculture ad Agro-Based Industry Malaysia [7], 75,370 hectare areas were planted with durian in 2014 contributing to the durian fruit production of 376,565 metric tons. Besides, out of 250,000 million tons, 60–70% which is equivalent to 85,000 million tons of waste is actually collected [8] and the huge amounts of the rind disposition as waste could lead to environmental problems [9]. It was expected that DSF will be great potential in future specifically for one time used application such as packaging even though durian skin fiber (DSF) is a new source of natural fiber [10]. Nevertheless, it was still sorely lacking studies that have been conducted to investigate the utilization of durian skin as an alternative pulp and paper raw material.

Our previous preliminary study by Masrol *et al.* [11,12] has successfully produced and investigated the characteristics of paper made from durian rind chemi-mechanical pulp (CMP). However, a different type of pulping method was proposed as an improvement step for the characteristics of durian rinds paper. To extend the research work, this study proposed Soda-Anthraquinone chemical pulping process to produce durian rinds pulp. In this preliminary test, the durian rind Soda-AQ linerboard and corrugated medium fluting paper characteristics were examined and investigated in order to reveal the promising potential of durian rind as an alternative non-wood based raw material for papermaking and packaging. Consequently, the findings of this study would be beneficial for the durian rind pulp and paper research and development.

2. Experimental

2.1. Raw material preparation

Durian rinds were collected from a local durian flesh manufacturer at Batu Pahat, Johor, Malaysia. Only durian rinds from a variety of D24 were collected to control the experimental parameters. Firstly, durian rinds were cleaned from the residual aril and dirt. Next, durian rinds were sliced, spine removed, cubed and dried naturally according to Masrol *et al.* [11,12]. Finally, dried durian rind (Figure 1) was kept inside the air tight storage to prevent moisture and fungus.

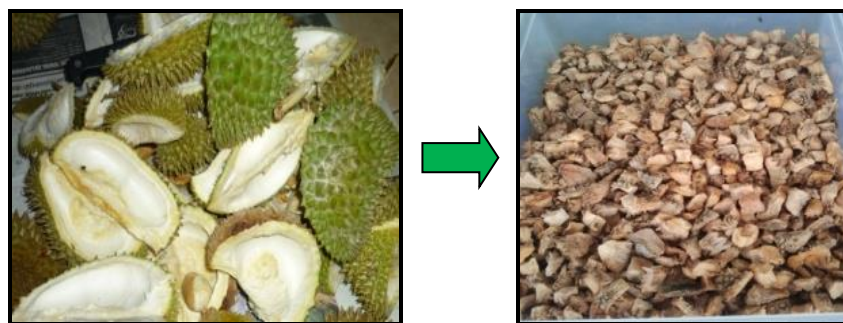


Figure 1. Naturally dried durian rinds cubes

2.2. Soda Anthraquinone pulping

Dried durian rinds (1000g oven dried (o.d.) weight) in Figure 1 were placed inside a rotary digester in Figure 2(a) and pulped using Soda-AQ pulping process according to the cooking conditions with active alkali concentration (20%), AQ charge (0.1%), liquor to material o.d ratio (7:1), time to maximum temperature (90 minutes), time at maximum temperature (120 minutes) and maximum

cooking temperature (170°C). Figure 2(b) shows durian rind pulp produced via Soda-AQ. After the completion of the digestion process, the pulps were disintegrated in a hydro-pulper for 5 minutes and washed thoroughly with running water on a fine filter in order to remove the remaining black liquor. Then, the screening process was carried out using PTI Sommerville Fractionators with accordance to TAPPI T 275 standard with a slot size of 0.15 mm. After that, a spin-dry Neng Shin extractor is used to remove excess water and the screened pulp was dispersed using the Hobart mixer. Finally, durian rind Soda-AQ pulps were sealed in the plastic bags and kept inside a cold chiller at a temperature of 6°C for further process and analysis. Figure 3 shows the flow chart of durian rind pulping via the soda-AQ pulping process.



Figure 2. Soda-AQ pulping: (a) Rotary digester, and (b) Durian rind Soda-AQ pulp

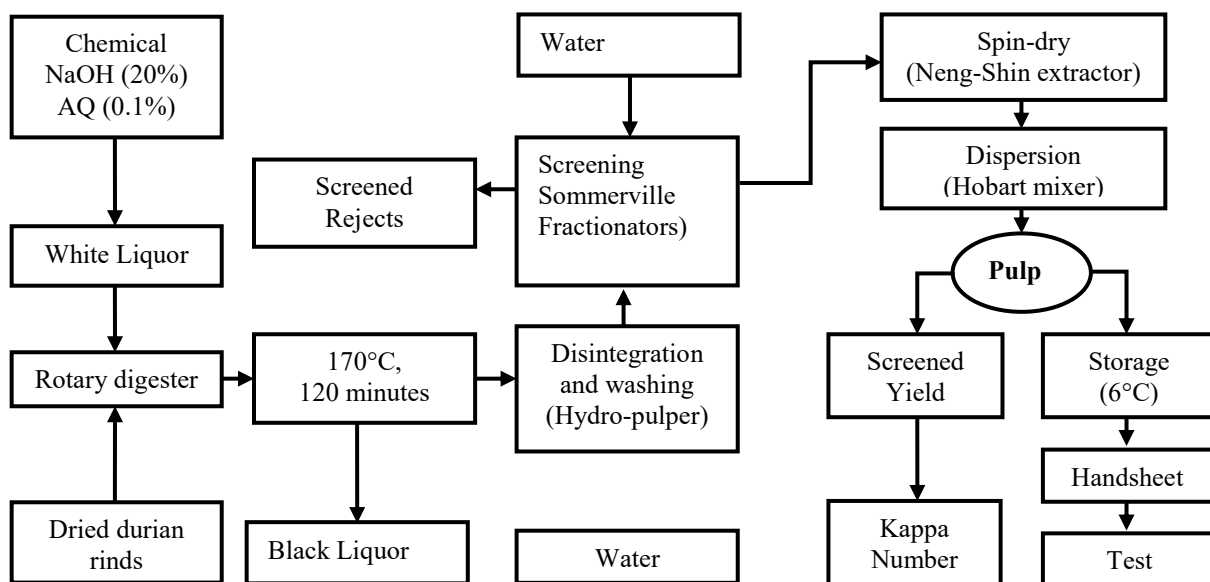


Figure 3. Flowchart of durian rinds pulping via Soda-Anthraquinone process

2.3. Laboratory hand-sheets preparation

For evaluation, linerboard hand sheets with a basis weight of $120 \pm 3 \text{ g/m}^2$ were produced from unbleached and unbeaten durian rinds soda-AQ pulp by semi-automatic sheet machine (British Hand-sheet Machine) according to MS ISO 5269-1:2007, IDT Pulps – Preparation of Laboratory Sheets for Physical Testing –Part 1: Conventional Sheet-Former Method. Figure 4 shows the hand sheets

preparation process flow chart. 42 g oven dried (o.d.) weight of durian rinds Soda-AQ pulp were disintegrated for 2000 revolutions to disperse the bundled pulp with the addition of 2 liters of water into the disintegrator tank. After completion, the disintegrated pulp from the disintegrator tank was poured into the stock divider. The water level inside the stock divider was raised up to 14 liters level and pneumatics air bubble is used to mix the pulp and water evenly. The freeness test (2sets with 1 liter of diluted pulp per set) was performed according to the TAPPI T 227 om-99: Freeness of Pulp (Canadian Standard Method). To achieved a basis weight of 120 g/m², 2 sets of correction test (1 liter of diluted pulp per set) were performed to check whether the weight of the paper sheet is over or lower than as standard weight (approximately 2.44g). The correction test paper sheets were produced by the paper sheet former and dried with the rapid flat dryer at 105°C, and weighed. Water was discharged if the hand sheet weight exceeds the standard value or vice versa. After the correction test was performed on the stock preparation, the process continues with the preparation of 11-13 paper sheets (1 liter of pulp per sheet) by the semi-automatic sheet machine. After completion, all laboratory hand sheets that attached to the couch blotter were stacked on 2-3 pieces of dry blotter and covered by a polished plate on the top of it located to the center of the press machine flat base by using a guide. The stacked hand sheets were pressed approximately at 345 kPa for about 5 minutes in order to remove the residual water content and achieved the synchronized thickness. The pressing procedure was repeated for another session with the same pressure and time after changing the blotter paper between the sheets. The paper sheets that attached to the surface of polished steel plate then were fixed above and below to the stack of standard drying rings to make sure the hand sheets are dried uniformly. A heavy weight was placed at the top of the drying ring to give the pressure to the edge of paper sheets. Finally, the hand sheets were dried for 24 hours and conditioned for another 24 hours inside a control room at 23 ± 1 °C and $50 \pm 2.0\%$ RH according to TAPPI T 402 sp-03 Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products and MS ISO 187: 2001, IDT for further evaluation and analysis.

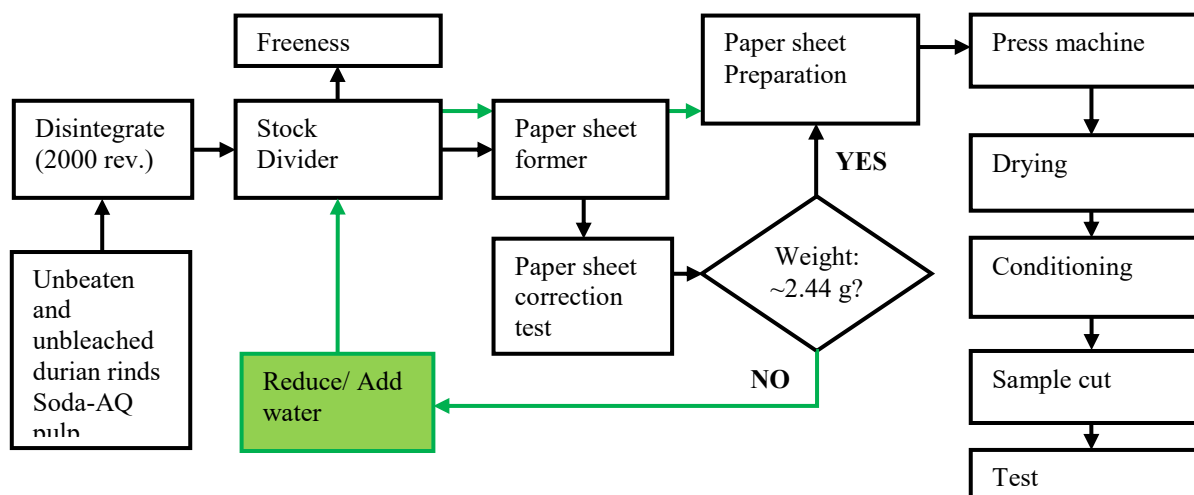


Figure 4. Flowchart of durian rind Soda-AQ linerboard preparation process

2.4. Characteristics test

The characteristics tests were conducted according to ISO 5270: 2012 “Pulps - Laboratory sheets - Determination of physical properties”. The samples were evaluated according to Malaysian Standard Methods (MS ISO) for various physical mechanical and optical properties, including grammage (MS ISO 536 : 2001, IDT), thickness (MS ISO 534: 2007, IDT), brightness (MS ISO 2470-1: 2010), opacity (MS ISO 2471: 2010), Tensile (MS ISO 1924-2), Tearing (MS ISO 1974 : 1999), bursting strength (MS ISO 2758 : 2007) and folding (MS ISO 5626 : 1999). A ring crush test (RCT) was performed on the durian rinds linerboard according to TAPPI T809 om-93. Flat crush test for corrugated medium

(CMT test) was conducted according to TAPPI T818. Water absorptiveness rate (Cobb₃₀) was determined according to MS ISO 535: 2001. The test was conducted in a controlled temperature and humidity environment as stipulated in TAPPI T 402 sp-03 Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products and MS ISO 187: 2001, IDT. The sampling was conducted according to TAPPI T400 and MS ISO 186: 2002, IDT.

3. Results and Discussion

3.1. Durian rind Soda-AQ 120 gsm linerboard characteristics

Table 1 shows the characteristics of durian rind Soda-AQ linerboard and corrugated medium paper. For optical characteristics, Soda-AQ pulp ISO brightness (19.21%) recorded a better value compared to CMP pulp (13.2%) by Masrol *et al.* [11]. Based on the tensile index, tear index and burst index, durian rinds Soda-AQ pulp shows better mechanical characteristics compared to chemi-mechanical pulp (CMP) developed by our previous study [11]. That was due to the effects of Soda-AQ pulping variables combination which are temperature, time, active alkali percentage and addition of anthraquinone (AQ) compare with the previous CMP pulping with only cold chemical treatment and subsequent refining process[11]. The similar finding was reported by Khristova and Tissot[13], where tensile, tear and burst index of *Calotropis procera* (usher) soda-AQ pulp were higher than the chemi-mechanical pulp (CMP). The strength of paper can be evaluated from its tensile, bursting and tearing strength, stiffness is evaluated with CMT, RCT and resistance to folding [14]. Durian rind Soda-AQ 120 gsm paper recorded value of 292, 1.53kN/m and 70.5 N for number of folds, RCT and CMT respectively.

3.2. Comparative results of tensile index, tear index and burst index

Table 2 shows the comparative characteristics of durian rind linerboard characteristics with another type of paper reported by previous studies. For tensile index, durian rind Soda-AQ paper shows better value than kenaf bast [15], old corrugated carton(OCC) [16–18], Bagasse [17], wheat straw [18], Coir soda-AQ [19], oil palm empty fruit bunch(EFB) [20], *Acacia Mangium* [20], *Eucalyptus Globulus* [20], Rapeseed [21], Semantan Bamboo [22], Coir CMP [23] and NSSC [24,25] . Durian rind Soda-AQ paper shows better tear index than paper made from kenaf core [16], bagasse [17], OCC [17], EFB [20], *Acacia Mangium* [20], *Eucalyptus Globulus* [20], rapeseed [21] and NSSC [24,25] but slightly similar with OCC [16–18] and coir CMP [23]. The results in Table 1 also shows that the burst index of the 120 gsm paper produced from durian rind Soda-AQ pulp is higher than paper sheet made of Kenaf Bast [15], OCC, Bagasse [17], EFB [20], *Acacia Mangium* [20], *Eucalyptus Globulus* [20], rapeseed [21], Semantan Bamboo [22], Coir CMP [23] and NSSC [24,25]. Therefore, it is specified that the 120 gsm paper sheets made from durian rind Soda-AQ pulp have comparable tensile, tear and burst characteristics to the other types of paper reported by previous studies.

3.3. Comparative results of bulk density, burst index, CMT and RCT with other types and commercial paper

Table 3 shows that durian rind Soda-AQ 120 gsm linerboards characteristics were comparable with another type of paper from previous studies and commercial linerboards. Apparent density is one of the most significant properties of paper and influences almost all mechanical, physical, and electrical properties [20]. The bulk density (0.672 g/cm³) of durian rind linerboard shows slightly similar results with some of the non-wood based and commercial linerboard. The burst index recorded a value of 3.12 kPa.m²/g which comparable with other commercial linerboards. Durian rind Soda-AQ 120 gsm linerboard shows the value of 1.53 kN/m and 2.00 N.m²/g for RCT and RCT index respectively. It can be seen that ring crush test (RCT) value is comparable with another types of linerboard and achieved a minimum level requirement for commercial linerboard in Malaysia such GSPP [19] and Pascorp [19]. RCT (0.00131 kN.m/g) recorded a lower value compared to *Mischantus* and CF pulp [26] Meanwhile, for CMT result, durian rind corrugated medium paper shows a lower value than other type and

commercial paper [17–19,24,25,27,28] except old corrugated carton (OCC) linerboard [17]. CMT index (0.61 N.m²/g) also shows lower value than other types of paper [20,26,29]. Consequently, durian rind linerboard and corrugated medium had shown comparable and promising quality compared to another type of paper and also commercial paper. However, the low condition of CMT could be improved by beating revolutions and the addition of dry strength agent in the future.

Table 1. Durian rind 120 gsm Soda-AQ paper characteristics

Characteristics	Durian rind soda-AQ 120 gsm linerboard	
	Mean	STDV
Paper bulk density (g/cm ³)	0.672	0.006
ISO brightness (%)	19.21	0.753
ISO opacity (%)	98.32	0.109
Tensile index (N.m/g)	57.591	0.195
Tearing index (mN.m ² /g)	7.087	0.188
Bursting index (kPa.m ² /g)	3.12	0.02
Double fold, No.	292	15
RCT(kN/m)	1.53	0.02
CMT (N)	70.5	3.54
Cobb ₃₀ (g/m ²)	133.20	5.93

Table 2. Comparative mechanical characteristics of durian rind 120 gsm Soda-AQ paper

Paper type	TI (N.m/g)	TE (mN.m ² /g)	BI (kPa.m ² /g)
Durian Soda-AQ	57.59	7.09	3.12
Kenaf KHK[15]	71.03	13.38	4.18
Kenaf KKK[15]	78.84	15.11	5.12
Kenaf Bast[15]	40.83	20.68	2.66
Kenaf Core[15]	83.09	5.87	6.09
^b Kenaf KHK[16]	78.21	14.35	5.21
^b Kenaf KKK[16]	86.10	14.36	5.90
^b Kenaf Bast[16]	72.47	23.95	4.70
^b OCC[16]	42.27	7.02	2.79
^b USWK[16]	95.18	12.49	7.23
Bagasse[17]	43.60	5.47	2.63
OCC[17]	17.90	5.14	0.63
Wheat straw[18]	67.9	7.3	5.7
OCC[18]	19.4	7.1	1.3
^a Coir Soda-AQ[19]	44.66	11.76	4.57
EFB[20]	21.37	5.85	1.41
<i>Acacia Mangium</i> [20]	2.53	3.28	6.76
<i>Eucalyptus Globulus</i> [20]	24.84	4.33	0.13
Rapeseed[21]	25.57	3.70	1.24
^a Semantan Bamboo[22]	32.54	13.45	1.54
Coir CMP[23]	18.33	7.05	1.85
NSSC[24]	14.24	5.21	0.96
NSSC[25]	12.20	6.20	0.94

a= optimum pulp; b : beaten pulp; TI : tensile index; TE ; tear index; BI : burst index

Table 3. Comparative bulk density, burst index, RCT and CMT of durian rind Soda-AQ linerboard

Paper type	Bulk density (g/cm ³)	Bulk density (cm ³ /g)	BI (kPa.m ² /g)	RCT (kN/m)	RCT (N)	RCT (N.m ² /g)	RCT (kN.m/g)	CMT (N)	CMT (N.m ² /g)
Durian Soda-AQ	0.672	1.49	3.12	1.53	232.5	2.00	0.00131	70.5	0.61
Kenaf Core[15]	0.716	-	4.18	-	-	2.87	-	-	-
Kenaf KHK[15]	0.590	-	5.12	-	-	1.85	-	-	-
Kenaf KLK[15]	0.620	-	2.66	-	-	2.25	-	-	-
Kenaf Bast[15]	0.502	-	6.09	-	-	1.43	-	-	-
^b Kenaf KHK[16]	0.651	-	5.21	-	-	2.25	-	-	-
^b Kenaf KLK[16]	0.672	-	5.90	-	-	2.68	-	-	-
^b Kenaf Bast[16]	0.594	-	4.70	-	-	2.61	-	-	-
^b OCC[16]	0.533	-	2.79	-	-	1.32	-	-	-
^b OSWK[16]	0.723	-	7.23	-	-	3.14	-	-	-
Coir[19], [27]	0.71	-	4.57	-	-	1.76	-	87	-
GSPP IKL1[19]	0.68	-	≥ 3.12	-	-	≥ 1.39	-	-	-
GSPP IKL2[19]	0.73	-	≥ 3.12	-	-	≥ 1.47	-	-	-
GSPP IKL3[19]	0.79	-	≥ 2.85	-	-	≥ 1.71	-	-	-
GSPP IKL4[19]	0.72	-	≥ 2.70	-	-	≥ 1.58	-	-	-
GSPP IL1[19]	0.68	-	≥ 2.09	-	-	≥ 1.13	-	-	-
GSPP IL2[19]	0.72	-	≥ 2.09	-	-	≥ 1.27	-	-	-
GSPP IL3[19]	0.79	-	≥ 1.80	-	-	≥ 1.38	-	-	-
GSPP IL4[19]	0.79	-	≥ 1.80	-	-	≥ 1.04	-	-	-
GSPP IL5[19]	0.74	-	≥ 1.80	-	-	≥ 1.03	-	-	-
GSPP IL6[19]	0.81	-	≥ 1.80	-	-	≥ 1.03	-	-	-
Pascorp IL1[19]	0.71	-	≥ 2.00	-	-	≥ 1.11	-	-	-
Pascorp IL2[19]	0.70	-	≥ 2.09	-	-	≥ 1.14	-	-	-
Pascorp IL3[19]	0.71	-	≥ 2.09	-	-	≥ 1.13	-	-	-
Pascorp IL4[19]	0.72	-	≥ 2.00	-	-	≥ 1.21	-	-	-
Pascorp IL5[19]	0.71	-	≥ 2.00	-	-	≥ 1.26	-	-	-
Pascorp IL6[19]	0.70	-	≥ 2.00	-	-	≥ 1.30	-	-	-
SANYEN 6[20]	-	1.49	2.54	1.4	-	-	-	-	1.6
SANYEN 13[20]	-	1.51	2.30	1.5	-	-	-	-	1.5
SANYEN 20[20]	-	1.55	1.92	1.4	-	-	-	-	1.5
SANYEN 26[20]	-	1.58	1.95	1.3	-	-	-	-	1.6
SANYEN 40[20]	-	1.56	1.55	1.1	-	-	-	-	1.0
SANYEN 50[20]	-	1.87	1.59	1.2	-	-	-	-	1.3
TRIO25[20]	-	1.93	1.71	1.2	-	-	-	-	1.2
TRIO45[20]	-	1.82	1.67	1.1	-	-	-	-	1.2
TRIO50[20]	-	1.76	1.75	1.0	-	-	-	-	1.2
PASCORP20[20]	-	1.68	1.40	1.1	-	-	-	-	1.3
PASCORP25[20]	-	1.82	1.25	1.1	-	-	-	-	1.3
100% Old OCC[20]	-	1.79	1.54	1.3	-	-	-	-	1.3
Bagasse[17]	0.68	-	2.63	-	-	-	-	350	-
OCC[17]	0.46	-	0.633	-	-	-	-	64.5	-
Wheat straw[18]	-	-	5.7	-	289	-	-	330	-
OCC[18]	-	-	1.3	-	124	-	-	103	-
Wheat straw+ OCC[18]	-	-	4.0	-	250	-	-	260	-
NSSC[24]	-	-	0.96	-	143.5	-	-	346.2	-
NSSC[25]	-	-	0.94	-	166.0	-	-	377	-
Mischantus[26]	-	-	2.30	-	-	-	0.00578	-	1.54
CF pulp[26]	-	-	1.677	-	-	-	0.00430	-	1.065
Wheat straw Semi-chemical[28]	-	1.3	3.2	-	-	-	-	290	-
Recycled paper[28]	-	1.5	2.9	-	-	-	-	195	-
Semantan bamboo[29]	-	-	-	-	-	-	-	-	1.04
Long fiber[29]	-	-	-	-	-	-	-	-	1.78
Kenaf[29]	-	-	-	-	-	-	-	-	0.98

a= optimum pulp; b : beaten pulp

3.4. Water absorptiveness

Cobb value represents the amount of water absorbed by paper (g/m^2) after bearing water for a given time [30], such as 30s in the current study. The smaller the Cobb value, the better the water resistance of the paper [30]. The Cobb₃₀ results in Table 4 indicated that water penetrated linerboard made from 100% virgin durian rind soda-AQ pulp to fast. This observation was similar with previous researches that founded high water penetration for the paper pulp without any or low addition of hydrophobic material [31–33]. It can be seen durian rind soda-AQ linerboard water absorptiveness (133.20 g/m^2) recorded a lower water resistance compared to 130 gsm linerboard [30], softwood [34], bagasse [34] and KS170 linerboards [35] but better than others [33,36]. This meaningful result could offer improvements steps for durian rind water absorptiveness quality. In order to improve the water absorptiveness of durian rinds Soda-AQ linerboard, the addition of hydrophobic and coating material should be considered in the future.

Table 4. Comparative Cobb test of durian rind 120 gsm Soda-AQ paper

Type of paper	Cobb test
Durian rinds	133.20
Linerboard(130 gsm) [30]	92.1
Jute paper[33]	557.33
Softwood[34]	78
Bagasse[34]	63.2
KS170 Linerboards[35]	24.02
Bamboo bleached DQP[36]	~250
Bamboo bleached CEH[36]	~285
Northern Pines Bleached Softwood (NSBK) [36]	~260

3.5. Scanning Electron Microscopy (SEM) Image Analysis

Figure 5 shows the surface morphology of 120 gsm paper with 500x magnification. Durian rind Soda-AQ paper shows smoother, more uniform and better compactness of fiber compared to rougher durian rinds CMP paper in Figure 6. The fiber formation in durian rind Soda-AQ paper is more straight and less of kinks. Soda-AQ paper shows better fiber to fiber bonding that leads to better mechanical characteristics. Cross-section SEM image in Figure 7 shows the compactness of 120 gsm durian rind soda-AQ linerboard.

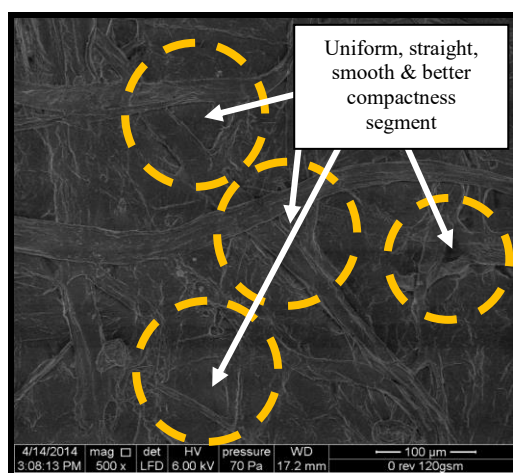


Figure 5. SEM image of 120 gsm durian rind Soda-AQ linerboard surface at 500 x magnifications

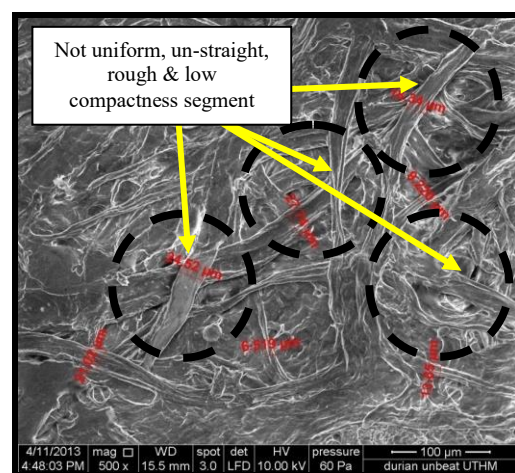


Figure 6. SEM image of 60 gsm durian rind CMP surface at 500 x magnifications (reprinted from Masrol *et al.* [11])

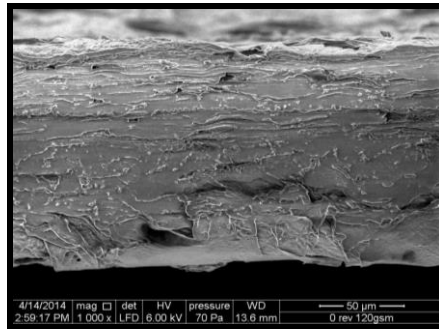


Figure 7. SEM image of 120 gsm durian rind Soda-AQ linerboard cross section (1000 x magnifications)

4. Conclusion

In conclusion, this preliminary study has successfully produced and investigated the characteristics of linerboard and corrugated medium paper made from durian rinds pulp via chemical pulping method of Soda-Anthraquinone (Soda-AQ). In comparison to the other material type and commercial paper, durian rinds were acceptable for producing linerboards. Based on the results of bulk density, burst index and RCT, durian rinds Soda-AQ linerboard also recorded comparable results with industrial linerboards. Besides, durian rinds Soda-AQ corrugated medium paper recorded low CMT value compared to other material type and commercial paper. However, in order to increase the quality of durian rinds Soda-AQ linerboard and corrugated medium paper, continuous improvement needs to be considered. As a recommendation, an optimum pulp could be produced by optimization process of Soda-AQ pulping variables such as active alkali concentration, Anthraquinone charge, time at maximum temperature and maximum temperature. Mechanical treatment such as beating or refining process should be applied in order to increase fiber to fiber bonding that leads to characteristics improvement. Furthermore, the addition of dry strength agent also recommended to enhance the linerboards and corrugated medium characteristics especially RCT, CMT and water absorptiveness value. The results of this study will trigger a more in-depth study of the use of the durian skin as an alternative raw material for the production of pulp and paper.

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