AFSSAAE

Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering 2021, 4(1), 68-75
ISSN 2622-5921

ORIGINAL RESEARCH Open Access

Cardboard formulation made from banana stalks and coconut coir using linear programming method

Azimmatul Ihwah *, Retno Astuti, E. F. Sri Maryani Santoso, Afifah Ulfah

Department Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

KEYWORDS

Banana stalks
Cardboard
Coconut coir
Linear programming
Tapioca

ABSTRACT

Malang Regency produced 690,136 tons banana in 2016. The banana production is in line with the waste (banana stalks). Banana stalks contain 83.3% cellulose and 2.97% lignin, of which can be used as raw material for paperboard making. However, the banana leaf paper has a low tensile strength of 7.45 N/mm^2, so additional fibers to strengthen the paper is necessary, such as coconut coir which has a tensile strength of 46.67 N/mm^2. This research aimed to formulate the material for paper making, such as the fiber source (banana fronds and coconut coir), filler (tapioca), and water to produce paperboard with minimal costs. The research was conducted using a linear programming method with LINDO software. The formulation of a sheet of cardboard produced was 34.79 g of dry banana stalks, 19.20 g of coconut coir, 6.00 g of tapioca, 136.08 g of NaOH, 2080 mL of distilled water, and 1000 mL of water with manufacturing cost of IDR 6,931.15. The paper characteristics has gramature of 323.8 g/m^2, moisture content of 19.75%, water absorption test of 743.2 g/m^2, tensile resistance of 1.4 kN/m, and stiffness of 5.7 mN.m.

Introduction

Waste is a substance or object that is deliberately disposed of, must be disposed of, and disposed of from a production process and residual consumption or the result of a failure of activities (Bassett, 1999). One type of waste is agricultural waste. Agricultural waste is waste generated from agricultural operations, such as manure and waste from the harvesting process (Lin et al., 2021).

According to the Agriculture Data Center and Information System of the Ministry of Agriculture in 2016, East Java is the province with the largest banana production in Indonesia with the highest banana production in Malang Regency at 42.35% or 690,136 tons. The banana plant is an annual plant which when it dies will be left to become fertilizer. Thus, the plant parts, especially banana leaves, are not used.

Banana plants have several parts including fruit, stems, leaves, and roots. Banana fruit is used for direct consumption. Banana leaves contain polyphenol compounds (EGCG) and wax substances that are used as traditional food wrappers, wedding delivery, and feast (Fereidoon and Priyatharini, 2015). Banana stems are used as compost, crafts such as bags, wallets, wall hangings, frames (Suharyani et al., 2014); furniture (Fauziati., 2008); straps or material for sacks, leather puppets, animal feed, and the raft (Anuja, 2019). The high fiber content in banana stalks can be used as raw material for the cardboard-making process.

Paper is a thin layer consisting mostly of fibers that are processed into pulp and dried (Holik, 2006). In Asia, the need for paperboard reaches 52% of total global consumption (Kayo et al, 2015). East Java is one of the paper/cardboard exporting producers with a total of US $ 91.33 million in 2012; and contributes 23% of the national paper industry in 2019 (Syarief, 2019).

One type of paper produced from banana fronds is art paper which is more elastic and brown in color. In another study, the resulting banana stalk paper had a low tensile strength of 7.45 N/mm^2 (Khan et al., 2014). Thus, it is necessary to add other fiber raw materials to enhance the tensile strength. The additional fiber raw material chosen is coconut coir.

*Corresponding author
E-mail address: azimmatul.ihwah@ub.ac.id

Received on 6 November 2020, revised on 3 March 2021, accepted on 19 July 2021

Coconut coir is the largest component in coconut fruit, accounted for 35%. Coconut coir has characteristics of hardly to broken down, resistant to water, difficult to rot, has high flexibility, has high availability, and easy to find (Majid, 2011). In Malang City, the average coconut coir waste that is disposed of reaches 10 kg per day or about 1.96 tons per week from 28 traditional markets. No proper waste treatment is currently applied, therefore the waste is only dumped on the market or burned (Joothi, 2015). Coconut coir contains 19.26-23.87% cellulose, 29.33-31.64% lignin, 8.15-8.50% hemicellulose, 14.25-14.85% pectin, tannins, and other ingredients (Esmeraldo et al., 2010); and has a tensile strength of 46.67 N/mm^2.

Therefore, this research was carried out to determine the formulation proportions of the amount of material for making paper, namely fiber (banana and coconut coir), filler (tapioca), and water to produce paperboard with minimal costs. The research was conducted using a linear programming method using LINDO software. Linear programming is a mathematical model that can represent objective functions (objectives) and resource limitations as a system of linear equations (Markland, 1983). Linear programming has 4 modelling variables, namely decision variables, objective functions, constraint functions, and parameters (Lewis, 2008). The formulation process aimed to minimise paperboard production costs. The decision variables being sought were banana stalk, coconut coir, and tapioca. The constraint factors used as the limit are fiber, filler, banana fronds, coconut coir constraints, and equality constraints. In this study, it is expected that the model formulation can produce the best proportion of cardboard.

Methods

This research was conducted in the Agrochemical Technology Laboratory, Department of Agro-industrial Technology, Universitas Brawijaya and the data was processed in the Agro-industry Management Laboratory, Department of Agro-industrial Technology, Universitas Brawijaya.

Materials

The pulping process used in this study was the soda process. Thus, the main ingredients included old coconut coir obtained from sellers of grated coconut in Pandanwangi traditional market, Malang City and banana stems from Kebonagung, Pakisaji, Malang, East Java. Additional materials used were tapioca, sodium hydroxide (NaOH) pro-technis (p.t) with a purity of 78%, distilled water (H_2O), and water. Tapioca was used as filler.

Method

This study aimed to minimize the cost of producing paperboard obtained by adding up the cost of making banana leaf pulp, the cost of making coconut husk pulp, the cost of purchasing tapioca, and the cost of buying water. The cost of making banana stalk pulp consists of the sum of the purchase costs of banana stalks, the cost of purchasing NaOH, and the cost of purchasing distilled water. While the cost of making coconut husk pulp consists of the sum of the cost of buying coconut coir, the cost of purchasing NaOH, and the cost of purchasing distilled water. Thus, the components used in the system namely the amount of material used in the paperboard-making process with the attribute cost of purchasing materials. The following were the components of the amount of paperboard material:

1. The weight of banana stems
2. The amount of coconut husk
3. The amount of tapioca

with the attributes of the cost of purchasing materials include:

1. Cost of making banana stalk pulp
2. The cost of making coconut husk pulp
3. The purchase cost of tapioca used

For other components such as NaOH, distilled water and water were not included in the components because the three materials already have their respective reference terms. The calculation of the required amount of NaOH and distilled water used the ratio of banana / coconut husk) to distilled water used to dissolve NaOH, which is 1 (g): 20 (mL) (Rosa et al, 2010). In the process of making banana leaf pulp, the concentration of NaOH used was 3% (Dewi et al., 2019) and coconut husk pulp was 30% (Kurniasari, 2020).

Based on this, the objective functions used were:

$$\text{Min } Z = BP + BS + BT + K$$
$$= C_1X_1 + C_2X_2 + C_3X_3 + K \quad (1)$$

With the following descriptions:

$$BP = C_1X_1$$
$$= HP(X_1)+HN(3\%.20X_1)+HAq(20X_1+500) \quad (2)$$
$$BS = C_2X_2$$
$$= H_S(X_2)+HN(30\%.20X_2)+HAq(20X_2+500) \quad (3)$$
$$BT = C_3X_3$$
$$= HT(X_3) \quad (4)$$

Notes :

Z = total production cost (IDR)

C_1 = cost for making banana stalk pulp (IDR/g)

C_2 = cost for making coconut coir pulp (IDR/g)
C_3 = tapioca prices (IDR/g)
X_1 = the amount of banana stalks used (g)
X_2 = the amount of coconut coir used (g)
X_3 = the amount of tapioca used (g)
BP = banana stalks purchasing cost (IDR/g)
BS = coconut coir purchase cost (IDR/g)
BT = tapioca purchase cost (IDR/g)
K = water purchase cost (IDR/g; 1 g = 1 mL)
HP = banana stalks prices (IDR/g)
HS = coconut coir prices (IDR/g)
HT = tapioca prices (IDR/kg)
HN = NaOH prices (IDR/g)
Haq = aquades prices (IDR/g; 1 g = 1 mL)

In the system to be created, there are several constraints that affect it. This constraint will be a constraint function in the model which serves to limit the amount of material produced from the model. Thus, the paper results can be obtained according to the desired constraints or limitations. The constraint function used is:

Cellulose constraint:
$\alpha_{11}X_1 + \alpha_{12}X_2 + \alpha_{13}X_3 \leq S$ .... (5)
Banana stalks constraint:
$\alpha_{21}X_1 + \alpha_{22}X_2 + \alpha_{23}X \geq S_1$ .... (6)
Coconut coir constraint:
$\alpha_{31}X_1 + \alpha_{32}X_2 + \alpha_{33}X_3 \geq S_2$ .... (7)
Filler constraint:
$F_1 \leq \beta_{11}X_1 + \beta_{12}X_2 + \beta_{13}X_3 \leq F_2$ .... (8)
Similarity constraint:
$\gamma_{11}X_1 + \gamma_{12}X_2 + \gamma_{13}X_3 = B$ .... (9)
Non Negativity constraint:
$X_1, X_2, X_3 \geq 0$ .... (10)

Notes:
α_{11} = coefficient of banana stalks in cellulose constraint
α_{12} = coefficient of coconut coir in cellulose constraint
α_{13} = coefficient of tapioca in cellulose constraint
α_{21} = coefficient of banana stalks in banana stalks constraint
α_{22} = coefficient of banana stalks in banana stalks constraint
α_{23} = coefficient of tapioca in banana stalks constraint
α_{31} = coefficient of banana stalks in coconut coir constraint
α_{32} = coefficient of coconut coir in coconut coir constraint
α_{33} = coefficient of tapioca in coconut coir constraint
β_{11} = coefficient of banana stalks in minimum filler constraint
β_{12} = coefficient of coconut coir in minimum filler constraint
β_{13} = coefficient of tapioca in minimum filler constraint
γ_{11} = coefficient of banana stalks in similarity constraint
γ_{12} = coefficient of coconut coir in similarity constraint
γ_{13} = coefficient of tapioca in similarity constraint
X_1 = the amount of banana stalks used (g)
X_2 = the amount of coconut coir used (g)
X_3 = the amount of tapioca used (g)
S = total number of cellulose inside a cardboard (g)
S_1 = minimum amount of banana stalks cellulose inside a cardboard (g)
S_2 = minimum amount of coconut coir cellulose inside a cardboard (g)
F_1 = minimum filler content in paper making process (g)
F_2 = maximum filler content in paper making process (g)
B = composition amount of cellulose and tapioca inside a cardboard (g)

The purchase price of each ingredient include the purchase price for banana stalks, the purchase price for coconut coir, the purchase price for tapioca, the purchase price for distilled water, the purchase price for NaOH, and the purchase price for water, as shown in Table 1.

Based on these prices, the cost value of the objective function has the following results:

$BP = C_1X_1$
$= HP\,(X_1) + HN\,(3\%.20X_1) + Haq\,(20X_1 + 500)$
$= 1.5(X_1) + 24\,(3\%.20X_1) + 1.7\,(20X_1 + 500)$
$= 1.5X_1 + 14.4X_1 + 34X_1 + 850$
$= 49.9X_1 + 850$

$BS = C_2X_2$
$= HS\,(X_2) + HN\,(30\%.20X_2) + Haq\,(20X_2 + 500)$
$= 0.5\,(X_2) + 24\,(30\%.20X_2) + 1.7\,(20X_2 + 500)$
$= 0.5X_2 + 144X_2 + 34X_2 + 850$
$= 178.5X_2 + 850$

$BT = C_3X_3$
$= HT\,(X_3)$
$= 11X_3$

then,

$Min\ Z = BP + BS + BT + K$
$= C_1X_1 + C_2X_2 + C_3X_3 + K$
$=(49.9X_1+850)+(178.5X_2+850)+11X_3+0.00143\,(1000)$
$=49.9X_1 + 178.5X_2 + 11X_3 + 850 + 850 + 1.43$
$=49.9X_1 + 178.5X_2 + 11X_3 + 1{,}701.43$

In the constraint function, there are 4 constraints, namely:

1. Equality constraints: at one time a production process is produced a sheet of paper containing 100% fiber (banana and coconut husk) and tapioca with a total material weight of 60 g or 0.06 kg.
2. Fiber constraints: the total fibrous material in a sheet of paper is 90% (Holik, 2006). Thus, with a total of 60 g of material, the total fiber material is 54 g in a piece of cardboard.
3. Banana stalks constraints: the minimum total fiber of banana stalks in a piece of cardboard is 32%, therefore the minimum total fiber of banana stalks is 19.2 g

Table 1. The price of each ingredient

Material	Price/kg (IDR)	Price/g (IDR)	Total amount used
Banana stalks	1,500	1.5	-
Coconut coir	500	0.5	-
NaOH	24,000	24	-
Distilled water	1,700	1.7	-
Tapioca	11,000	11	-
Water	1.43	0.00143	1,000 mL

Table 2. Output of running software LINDO

Variable	Value	Reduced Cost
X_1	34.799999	0.000000
X_2	19.200001	0.000000
X_3	6000000	0.000000

Row	Slack or Surplus	Dual Prices
2)	0000000	0.000000
3)	15.600000	0.000000
4)	0.000000	-128.600006
5)	3000000	0.000000
6)	0.000000	38.900002
7)	0.000000	-49.900002

4. Coir fiber constraints: the minimum total of coir fiber in a piece of cardboard is 32%, therefore the minimum total of coir fiber is 19.2 g
5. Filler constraints: based on statistical data from The Confederation of European Paper Industries (CEPI), the total filler on a sheet of paper is 10% (Holik, 2006). In this model, 5% of tapioca was used as filler. Thus, the maximum total of tapioca in a piece of cardboard is 6 g while the minimum total is 3 g.

The following models are made:

$$\text{Min } Zi = 49.9X_1 + 178.5X_2 + 11X_3 + 1{,}701.43$$

$$X_1 + X_2 \leq 54$$

$$X_1, X_2 \geq 19.2$$

$$X_3 \geq 3$$

$$X_3 \leq 6$$

$$X_1 + X_2 + X_3 = 60$$

$$X_1, X_2, X_3 \geq 0$$

Results and Discussion

Table 2 shows output the model carried out using LINDO. Based on the results of the LINDO running software, an optimal solution is obtained for the objective function value, namely the amount of material needed in the manufacture of paperboard with a paper size of 30 cm x 40 cm or 1,200 cm^2 with a thickness of 0.1 cm of 34.79 g for the amount of banana stalks (X_1), 19.20 g for the amount of coconut fiber (X_2), and 6.00 g for the amount of tapioca (X_3) at a cost of IDR 5,229.720 without additional water usage fees.

To calculate the amount of NaOH and distilled water used in each material, it can be seen as follows:

1. The amount of NaOH and distilled water in the making process of banana leaf pulp.

In the process of making banana leaf pulp using 3% NaOH concentration treatment at a temperature of 100 ^oC for 128 minutes. The calculation of the required amount of NaOH and distilled water uses a ratio of the amount of main raw materials (banana stalks) to the amount of distilled water used to dissolve NaOH of 1 (g): 20 (mL) (Surest and Satriawan, 2010). If the number of banana stems is 34.799999 g, the amount of distilled water is calculated as follows:

Ratio of raw material and distilled water used

$$= \frac{amount\ of\ raw\ material\ used}{amount\ of distilled\ water\ used}$$

$$\frac{1}{20} = \frac{34.799999}{x}$$

$$X = 695.999998 \text{ mL}$$

$$\approx 696 \text{ mL}$$

Based on these calculations, the amount of distilled water is 1196 mL which is obtained from the calculation of 696 mL + 500 mL, while the calculation of the amount of NaOH is done using the following calculation formula:

The amount of NaOH (g)

$$= \%N_aOHxthe\ amount\ of\ distilled\ water\ produced\ at\ a\ ratio\ of\ 1{:}\,20\ (mL)$$

$$= 3\% \text{ X } 695.999998$$

$$= 20.87999994 \text{ g}$$

Table 3. Result of sensitivity analysis

Variable	Obj. Coefficient Range		
	Current Coef.	Allowable Increase	Allowable Decrease
X_1	49.900002	128.600006	38.900002
X_2	178.500000	INFINITY	128.600006
X_3	11.000000	38.900002	INFINITY

Row	Right-hand Side Ranges		
	Current RHS	Allowable Increase	Allowable Decrease
2	54.000000	INFINITY	0.000000
3	19.200001	15.600000	INFINITY
4	19.200001	15.600000	19.200001
5	3.000000	3.000000	INFINITY
6	6.000000	15.600000	0.000000
7	60.000000	0.000000	15.600000

2. The amount of NaOH and distilled water in the coconut coir pulp making process.

In making coconut husk pulp using 30% NaOH treatment at a temperature of 100^o C for 150 minutes. The calculation of the required amount of NaOH and distilled water uses the same comparison formula as the process for making banana stem pulp. The amount of coconut husk needed is 19.200001 g, thus distilled water are needed with the following calculations,

Ratio of raw material and distilled water used

$$= \frac{number\ of\ raw\ material\ used}{number\ of\ aquades\ used}$$

$$\frac{1}{20} = \frac{19.200001}{x}$$

X = 384.000002 mL

≈ 384 mL

While the calculation of the amount of NaOH is done using the following formula:

The amount of NaOH (g)

=% NaOH X the amount of distilled water produced at a ratio of 1:20 (mL)

= 30% X 384.000002

= 115.2000006 g

Thus, it takes the amount of distilled water of 884 mL which is obtained from the calculation of 384 mL + 500 mL. Based on all these calculations, the calculation of the total costs incurred in making a piece of cardboard is obtained as follows:

The cost of making a piece of cardboard :

= BP + BS + BT + K

= $49.9X_1 + 178.5X_2 + 11X_3$ + 1,701.43

= 49.9 (34.799999) + 178.5 (19.200001) + 11 (6)+ 1,701.43

=1,736.5199501 + 3,427.20001785 + 66 + 1,701.43

= 6,931.14996795

≈IDR 6,931

The output shows several results in the form of reduced cost, slack/surplus and dual prices. Reduced cost is the cost that must be reduced to make the optimal solution of a positive variable (Ammar and Emsimir, 2020). The output shows a reduced cost value of 0, which means there are no reduction costs and the solution obtained is optimal. The slack/surplus variable indicates the amount of resources that are not used (remaining) or need to be added. The value of 0 in the slack/surplus variable shows that all resources have been used, such as the fiber constraint, coconut husk constraint, maximum filler constraint, and equality constraint. For banana stalks and minimum filler constraints, the slack/surplus value is not 0, meaning that there are resources that are not used (remaining) or need to be added. In the banana fronds constraint, the number of banana stems used was 34.799999, thus it needed an addition of 15.6. In the minimum filler constraint, the number of tapioca used was 6, therefore it needed an addition of 3. Dual prices are values indicating the changes in the objective function value due to the addition of 1 unit to the value of the right side (Alkubaisi, 2016). The value of dual prices of 0 indicates that, if the constraint capacity is increased by 1 unit, it will not affect the objective function value. This can be due to constraints that have not been fully utilized, thus if the capacity is added it will be useless.

In terms of coconut coir constraints and equality constraints, the dual price value is negative, which means that, if the capacity of each constraint is increased by 1 unit, it will cause a reduction of IDR 128.600006 (coconut husk constraint) and IDR 49.900002 (equality constraint). While, if the maximum filler constraint is increased by 1 unit, it will give an increase in the optimal solution value of the objective function of IDR. 38,900002. Based on the above statement, it is concluded that in making a sheet of cardboard, 34.799999 g of dry banana leaves are needed, 19.200001 g of coconut husk, 6.000 g of tapioca, 136.08000054 g of NaOH, 2080 mL of distilled water, and water. as much as 1000 mL at a cost of IDR 6,931.15. The model validation process was carried out by using a sensitivity analysis which can be seen in Table 3.

Figure 1. Appearance of the Resulted Cardboard

Table 4. The result of bending resistance, tensile resistance and water absorption

Parameter	Unit	Test result
Cobb 60	g/m^2	743.2
Bending (tensile) resistance	kN/m	1.4
Tensile resistance (stiffness)	mN.m	5.7

In the Obj Coefficient Range, Current coef. shows the value of the initial cost coefficient on each variable that can be tolerated an increase (allowable increase) and tolerable decrease (allowable decrease). Infinity shows that it increases or decreases at an infinite cost. The Righth and Side Ranges shows a change in the tolerable value of the right-hand side of the constraint function. It will result in a change in the value of the objective function according to the value of dual prices for each unit increase or decrease in capacity. For instance, the equality constraint is having an initial capacity amount of 60 g with no tolerable amount of increase capacity and a tolerable reduction amount of 15.6 g resulting in a reduced cost of IDR 49.900002 for each additional capacity unit. The appearance of the resulted cardboard can be seen in Figure 1. The paper is dark brown with a rough (fibrous) and dense texture.

The resulting paperboard has a gramature value obtained from the following calculations:

$$\text{Gramature } (g/m^2) = \frac{\text{each cardboard mass (g)}}{\text{each cardboard large } (m^2)}$$

$$= \frac{34}{0{,}1050}$$

$$= 323.8 \text{ g/m}^2$$

This value is in accordance with the provisions with a grammage greater than more than 225 g/m^2, which can be referred as paperboard (Holik, 2006). The resulted paperboard has a moisture content value of 19.75%, while the bending resistance, tensile resistance and water absorption test values are shown in Table 4.

The resulted paperboard has a water absorption value of 743.2 g/m^2. The water absorption value is directly proportional to the cellulose content of paper. This is because cellulose has hydrophilic or water-loving properties (Jonoobi et al., 2010). Banana and coconut coir stems have cellulose values of 53.8% and 22.58%, respectively, which results in cellulose values of 80.712% in banana pulp of and 65.941% in coconut coir pulp.

The resulting tensile resistance on the cardboard is 1.4 kN/m^2. The tensile resistance of paper is influenced by the cellulose content in the material, the concentration of the cooking solution, the length of cooking time, and the homogeneity of the adhesive (Zhong et al, 2017).

In the paperboard manufacturing process, the concentration of cooking solution (NaOH) used was 3% for banana frond pulp and 30% for coconut coir pulp with a cooking time of 128 minutes for banana frond pulp and 150 minutes for coconut husk pulp. This treatment resulted in the lignin value 2.636% for banana leaf pulp and 25.503% for coconut husk pulp, in which the initial lignin content in banana and coir stems was 6.4% and 61.42%, respectively. IIn the making of cardboard, the filler used is tapioca which serves to improve the surface texture (Martilla, 2012).

The homogenization process is carried out using a blender machine. The bending resistance or stiffness of paper is influenced by grammage (Seo, 2002). The higher the grammage value and the lower the water content, the higher the paper stiffness value (Lavoine et al., 2014). The resulted paperboard has a bending resistance value of 5.7 mN.m.

Conclusions

The formulation of a sheet of paperboard is produced with 34.79 g of dry banana stalks, 19.20 g of coconut husk, 6.000 g of tapioca, 136.08 g of NaOH, 2,080 mL of distilled water, and 1,000 mL of water at a cost of IDR 6,931. The characteristics of the resulted paperboard were having grammage of 323.8 g/m^2, moisture content of 19.75%, water absorption of 743.2 g/m^2, tensile resistance of 1.4 kN/m, and stiffness of 5.7 mN.m. Future research is needed to investigate the addition of other fibre materials (i.e. used paper) or filler (i.e. starch) to increase the tensile resistance of the paperboard.

References

Alkubaisi, M. W. (2016) ‘Shortcut methods for simplex-based sensitivity analysis of linear programming and related software issues’, *International Journal for Quality Research*, 11(1), pp. 209–220

Ammar, E. E., and Emsimir, A. A. (2020) ’A mathematical model for solving integer linear programming problems*’, African Journal of Mathematics and Computer Science Research*, 13(1), pp. 39-50

Anuja, D. (2019) ‘Banana stem: an under-utilised part of the plant’, *International Journal of Scientific Research*, 8 (10), pp. 24-25

Bassett, W. H. (1999) *Clay’s handbook of environmental health. 18th Ed*. London: E.& F. N. Spon.

Dewi, I. A., Ihwah, A., Setyawan, H. Y., Kurniasari, A. A. N., and Ulfah, A. (2019) ’Optimasi proses delignifikasi pelepah pisang untuk bahan baku pembuatan kertas seni (Optimization of banana leaf delignification as raw material in the making of art paper)’, *SEBATIK*, 23(2), pp. 447-454 [In Indonesian]

Esmeraldo, M., Gomes, A., Freitas, J., Fechine, P., Sombra, S., Corradini, E., Mele, G., Maffezzoli, A., and Mazzetto, S. (2010) ‘Dwarf-green coconut fibers: a versatile natural renewable raw bioresource. treatment, morphology, and physicochemical properties’, *Bioresources*, 5(4), pp. 2478-2501

Fauziati (2008) ’Pemanfaatan dan prospek pelepah batang pisang kepok sebagai bahan baku mebel (Utilization and prospect of *kepok* banana leaf as raw material in the furniture making)’, *Jurnal Riset Teknologi Industri*, 2(4), pp. 1-8 [In Indonesian]

Fereidoon, S., and Priyatharini, A. (2015) ’Phenolics and polyphenolics in foods, beverages and spices: antioxidant activity and health effects: a review’, *Journal of Functional Foods*, 18(1), pp. 820-897

Holik, H. (2006) *Handbook of paper and board*. Germany: WILEY-VCH Verlag GmbH & Co. KGaA.

Jonoobi, M., Jalaluddin, H., Aji, P. M., Mohb, Z. B. H., and Kristiina, O. (2010) ‘Preparation of cellulose nanofibers with hydrophobic surface characteristics’, *Journal Cellulose*, 17(2), pp. 299-307

Joothi, P. (2015) ‘Lignin and cellulose content in coir waste on subject to sequential washing’, *Journal Chemistry and Chemical Research*, 1(1), pp. 10-13

Kayo C., Oka, H., Hashimoto, S., Mizukami, M., and Takagi, S. (2015) ’Socioeconomic development and wood consumption’, *Journal of Forest Research*, 20(3), pp. 309-320

Khan, Md Z. H., Sarkar, M. A. R., Zahid, H. M., and Imam. (2014)’ Paper making from banana pseudo-stem: characterization and comparison’, *Journal of Natural Fibers*, 11(3), pp. 199-211

Kurniasari, A. A. N. (2020) ‘Optimasi delignifikasi pada proses pulping sabut kelapa tua (Cocus nucifera L.) (kajian konsentrasi NaOH dan lama waktu pemasakan) (Optimization of delignification in the pulping process of coconut coir using NaOH concentration and cooking time factors)’. Skripsi. Jurusan Teknologi Industri Pertanian, Fakultas Teknologi Pertanian, Universitas Brawijaya. [In Indonesian]

Lavoine, N., Desloges, I., Khelifi, B., and Bras, J. (2014) ‘Impact of different coating processes of microfibrillated cellulose on the mechanical and barrier properties of paper’, *Journal of Materials Science*, 49(1), pp. 2879–2893

Lewis, C. (2008) *Linear programming: theory and applications.* Austin: Universitas Texas.

Lin, C. S. K., Kaur, G., Li, C., and Yang, X. (2021) *Waste valorisation: waste streams in a circular economy*. New Jersey: Wiley & Sons Ltd.

Majid, A. (2011) ‘Coconut fibre: a versatile material and its applications in engineering: a review’, *Journal of Civil Engineering and Construction Technology*, 2(9), pp. 189-197

Markland, R. E. (1983) *Topics in managemen science*. Canada: John Wiley & Sons.

Martilla, E. 2012. Material design and technology of cartonboard packaging. skripsi. paper technology international pulp and paper technology. Tampere University.

Rosa, M. F., Medeiros, E. S., Malmonge, J. A., Gregorski, K. S., Wood, D. F., and Mattoso, L. H. C. (2010) ‘Cellulose nanowhiskers from coconut husk fibers: effect of preparation conditions on their thermal and morphological behavior’, *Journal Carbohydrate Polymers*, 8(1), pp. 83-92

Seo, Y. B. (2002) ‘New concept of stiffness improvement in paper and board’, *Journal of Korea TAPPI*, 34(5), pp. 63-69

Suharyani, Dhani, M., and Solikin, M. (2014). ‘Pemanfaatan limbah pelepah pisang raja susu untuk bahan material dinding kedap suara (Utilization of Raja Susu banana leaf waste as raw material of soundproof wall)’. Simposium

Nasional RAPI XIII - 2014 FT UMS. [In Indonesian]

Syarief, I. S. (2019). 'Industri kertas di Jatim mulai kehabisan bahan baku [online]. https://ekonomibisnis.suarasurabaya.net/news/2019/223424-Industri-Kertas-di-Jatim-Mulai-Kehabisan-Bahan-Baku (Accessed on 12 Februari 2019). [In Indonesian]

Zhong, L., Huimei, W. and Lanfeng, H. (2017) *Pulping and papermaking of non-wood fibers*. London: IntechOpen.