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Review on The Paper Making Process From Bamboo As A Paper Product

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Abstract: This study aims to review bamboo's papermaking process as a paper product. The loss of wood as the primary resource in pulp and the paper-based industry is the large scale of deforestation in Malaysia. Deforestation in Malaysia is an acute problem because its rate is rising quicker than any other tropical country in the world. Bamboo is a grass that can grow to 25 m in six months. When fully cultivated, it usually takes three to five years to grow to full strength. The fiber characterization, chemical analysis and paper properties have been review. The bamboo fiber has been evaluated using an image analyser. The result from this study showed that bamboo's average fiber length is around 2.29 mm for length, 16.4 µm for total width, 6.4 µm for wall thickness, and 3.5 µm for lumen diameter. The chemical properties were reviewed according to the TAPPI and ISO standard test method. The results showed that average bamboo had cellulose around 50 to 55 percent. The bamboo had a high ash content (2.20 %), mainly silica, and low content for lignin (25.50 %). From the reviewed for chemical pulping process it can be suggested that the kraft pulping with 18 percent of active alkali had the optimum properties of pulp and paper. The value of kappa number was around 20.03 percent, screen yield 44.40 percent and reject yield 0.31 percent. Meanwhile the optimum value for burst around 5.60 kN.m^2/g, tensile 5.763 (Nm/g)/10. All this result can be concluded that bamboo fiber is suitable to replace the wood fiber in papermaking.

Keywords: Bamboo Paper, Bamboo Kraft Pulping, Pulp Bamboo

1. Introduction

Paper is becoming an essential asset in society today because paper can convey the idea that media digital cannot. Due to the growing demand for paper products, the pulp and paper industries have risen. Paper use has also gradually increased worldwide. With the arrival of Information Technology (IT), the worldwide use of paper was projected to decrease as paperless communication was gradually deployed. Instead, though, the reverse has happened. Paper consumption in Malaysia has increased enormously from 1960 to 2005[1]. In Malaysia, the depletion of wood as the main resource in pulp and the paper-

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based industry is deforestation's massive scale. Deforestation is a sensitive issue in Malaysia as its rate is accelerating faster than any other tropical countries in the world a [2]. In Malaysia, around 124,000 metric tons of pulp for paper were obtained from wood resources that provide 184,000 metric tons of paper in 2002 [2].

Due to this, other means were implemented to avoid the wood resource being lost. Because of technology nowadays, wood pulp is not the only solution to make paper. There are many materials to make paper such as, bagasse, wheat, rice straws, bamboo, and kenaf [3]. To make a paper, fiber is needed. Fiber is a cellulosic element extracted from trees and used to make materials including paper, also there is nonwood fiber. Nonwood fibers, also referred to as ‘‘alternate fibers’’, are nonwoody cellulosic plant materials from which papermaking fibers can be extracted [3]. For example, bamboo in china is being explored as a useful raw material for papermaking [4].

Compared to softwood fibers, the typical fiber length of bamboo is about 2.29 mm in length, these bamboos can be used for more flexible paper goods than most other nonwood pulps due to the high strength of bamboo chemical pulps [5]. Because of its excellent pulp strength and fast recovery of chemicals, the kraft pulping process is the most popular pulping process in the world. Today, not only is the kraft process a dominant alkaline wood pulping process, but it is still the most common nonwood pulping process, such as bamboo.

The pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops, waste paper, or rags. Mixed with water and other chemical or plant-based additives, the pulp is the major raw material used in papermaking and other paper products' industrial production. In recent years, pulping studies of several bamboo species have revealed that a better fibre yield, higher xylan content and unchanged pulp viscosity can be achieved without affecting fibre length by reducing the cooking temperature and extending the cooking period [14]. Furthermore, the cooked bamboo was found to have higher alkali and sulphide yields and higher alpha-cellulose

2. Materials and Methods

The term ‘bamboo paper’ in the present review is used most broadly and the aim for this is to review the chemical analysis and fiber characterization of bamboo fiber, to review on the paper making process from bamboo as a paper product and to conclude and suggest the optimum pulp and paper properties from bamboo fiber

2.1 Data source

To locate published studies documenting bamboo as a paper product a systematic search for literature, independent of the year of publication, was carried out using the related electronic databases: Google scholar, ScienceDirect and Scopus. The literature search strategy combined the use of two primary key words: ‘bamboo’ and ‘paper’ These keywords were combined with other keywords such as ‘pulp and paper’, ‘bamboo fiber’, and ‘characterization’. to also explore the related existing research. The literature search was carried out over a four-month period, from September 2020 to January 2021, when the databases were accessed numerous times due to the difficulties of accessing some of the related sources and for more references. In addition, the references to the related research were reviewed in order to include additional studies in this study.

2.2 Study selection and data collection analysis

Retrieved studies were screened independently by the first author using titles of papers and abstracts. the full publication was retrieved and reviewed independently by the second author to determine the suitability based on the inclusion and exclusion criteria identified.

For collection criteria, the study had to consider whether to include soda pulping. However, the studies for soda pulping has been excluded from this review. The studies only carried out kraft pulping to considered for this review. A study involving bamboo paper with any type of bamboo has been considered in this review. Studies containing at least one intervention focused on the following result measures have been found to be included within this review: fiber characterization, chemical Composition of Bamboo, kraft cooking active alkali.

3. Fiber Characterization

Fiber characterization is critical in determining techno-commercial suitability and pulping process. Morphological characteristics are essential in estimating fibre quality, such as fibre length and width (Galal & Karar, 2004). Pulp technology uses fibers in wood and other pulping raw materials for all sorts of structural elements. The fibre measurements reflect the fitness of the fibrous pulp raw material. The average softwood, hardwood and bamboo fibre length are 3.5, 1.3 and 2.7 mm. It varies between and within species and trees and various locations. The fiber length is about 100 times that of its duration (Galal & Karar, 2004).

As a potential raw material for the Malaysian timber industry, bamboo has gained considerable attention. The bamboo plant can be harvested or produced on a large scale from its natural habitat (Ashaari et al., 2010). Bamboo has properties similar to certain timbers (Ashaari et al., 2010). It can also have longer fiber, making it ideal for paper and hardboard pulp processing. Due to its wide availability and the scarcity of softwood, bamboo has become an effective fiber reinforcement in Asian countries, particularly in India and China.

Bamboo fiber is a cellulosic fiber that is regenerated from a bamboo plant. It is a great perspective green fiber with outstanding biodegradable textile material, comparable to conventional glass fiber. The bamboo used for fiber preparation is usually 3–4 years old (Imadi S.R et al., 2014). Fiber is produced through alkaline hydrolysis and multi-phase bleaching of bamboo stems and leaves, followed by chemical treatment of starchy pulp generated during the process (Imadi S.R et al., 2014).

Annual bamboo fiber production is nearly 40000 tons and is increasing. Bamboo fiber is mainly produced from bamboo Phyllostachys Edulis, called 'Moso,' giant bamboo globally. Natural bamboo fiber (Figure 1) is similar to ramie fiber; however, they are more acceptable and shorter. As can be seen, the length of natural bamboo fiber is shallow, and therefore there might be problems with their processing. However, many woven and nonwoven products are made from such fiber. The chemical structure of the bamboo fiber is similar to that of wood. The main component is cellulose (about 57.00 – 63.00 %) with an α-cellulose content of 36.00 - 41.00 %, lignins (22.00 – 26.00 %), and pentosans (16.00 – 21.00 %)[11].

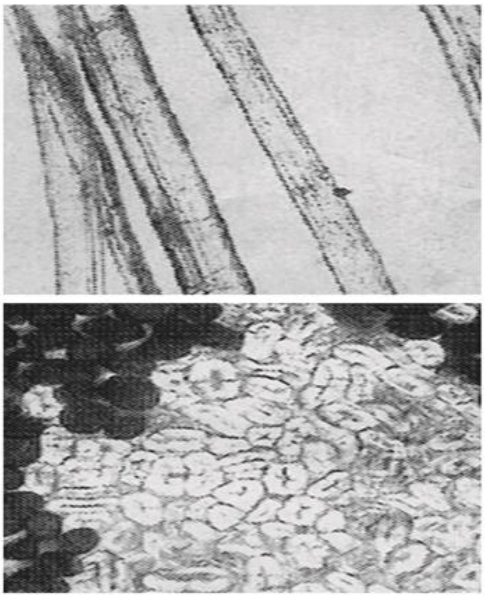

Figure 1: Longitudinal and cross-section view of natural bamboo fibres

3.1 Kraft Cooking

The kraft pulping process includes the digestion of wood chips at higher temperatures and pressure in "white liquor, " a sodium sulfide and sodium hydroxide water solution. The white liquor chemically dissolves the lignin that connects the cellulose fibers. Two types of digester systems are available, batch and continuous. Although the latest installations are continuous digesters, most kraft pulping is carried out in batch digesters. When cooking is complete in a batch digester, the digester's contents are transferred to an atmospheric tank, usually referred to as a blow tank. The blow tank's entire contents are sent to pulp washers, where the spent cooking liquor is separated from the pulp. The pulp then proceeds through various stages of washing and possibly bleaching, after which it is pressed and dried into the finished product. The "blow" does not apply to continuous digester systems.

The kraft process's balance is designed to recover the cooking chemicals and heat. Spent cooking liquor and the pulp wash water are combined to form a weak black liquor concentrated in a multiple-effect evaporator system to about 55.00 % solids. The black liquor is then further concentrated to 65.00 % solids in a direct-contact evaporator by bringing the liquor into contact with the flue gases from the recovery furnace or in an indirect-contact concentrator. The strong black liquor is then fired in a recovery furnace. Combustion of the organics dissolved in the black liquor provides heat for generating process steam and converting sodium sulfate to sodium sulfide. Inorganic chemicals present in the black liquor collect as a molten smelt at the furnace's bottom. The smelt is dissolved in water to form green liquor, which is transferred to a causticising tank where quicklime (calcium oxide) is added to convert the solution back to white liquor for return to the digester system. A lime mud precipitates from the causticising tank, after which it is calcined in a lime kiln to regenerate quicklime. For process heating, for driving equipment, for providing electric power, etc., many mills need more steam than can be provided by the recovery furnace alone. Thus, conventional industrial boilers that burn coal, oil, natural gas, or bark and wood are commonly used.

Bonfatti Júnior *et al.,* (2019) research evaluated the Bambusa vulgaris biomass's technological characteristics for pulp production by the kraft process. The Kraft cooking was carried out in a rotating autoclave containing individual stainless-steel capsules with a capacity of 450 mL each. The analyses were performed in three replicates according to the process conditions in Table 1.

Table 1: The conditions in the Kraft pulping process

Parameter	Conditions
AAA*	10, 12, 14, 16, 18, 20, 22 and 24
Sulfidity**	25
Maximum temperature (ºC)	170
Heating time (minutes)	90
Cooking time (minutes)	60
Liquor-to-biomass ratio (L·kg-1)	4
H factor	1100
Dry mass of chips (g)	70

3.2 Pulp Properties

The pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops, waste paper, or rags. Mixed with water and other chemical or plant-based additives, the pulp is the major raw material used in papermaking and other paper products' industrial production. In recent years, pulping studies of several bamboo species have revealed that a better fibre yield, higher xylan content and unchanged pulp viscosity can be achieved without affecting fibre length by reducing the cooking temperature and extending the cooking period [14]. Furthermore, the cooked bamboo was found to have higher alkali and sulphide yields and higher alpha-cellulose [14]. Bonfatti Júnior *et al.*, (2019) study the bamboo (Bambusa Vulgaris) state that The Bambusa vulgaris biomass presented screened yields much lower than the other two raw materials studied with 12.00 % of the active alkaline applied Figure 2(B). Besides, the specific consumption of the Bambusa vulgaris demonstrated strong growth, while with the other studied raw materials, this parameter showed a stable trend Figure 2 (E).

The specific consumption is based on the pulping yields and the basic density. This is an important parameter for pulp mills, and it reveals the necessity of the wood volume to achieve a certain production rate of the pulp. The species Bambusa vulgaris presents a lower screened yield for any kappa number range Figure 2(F). As previously mentioned, this fact is explained by the high extractive and ash contents presented in the species, causing a pulp yield decrease.

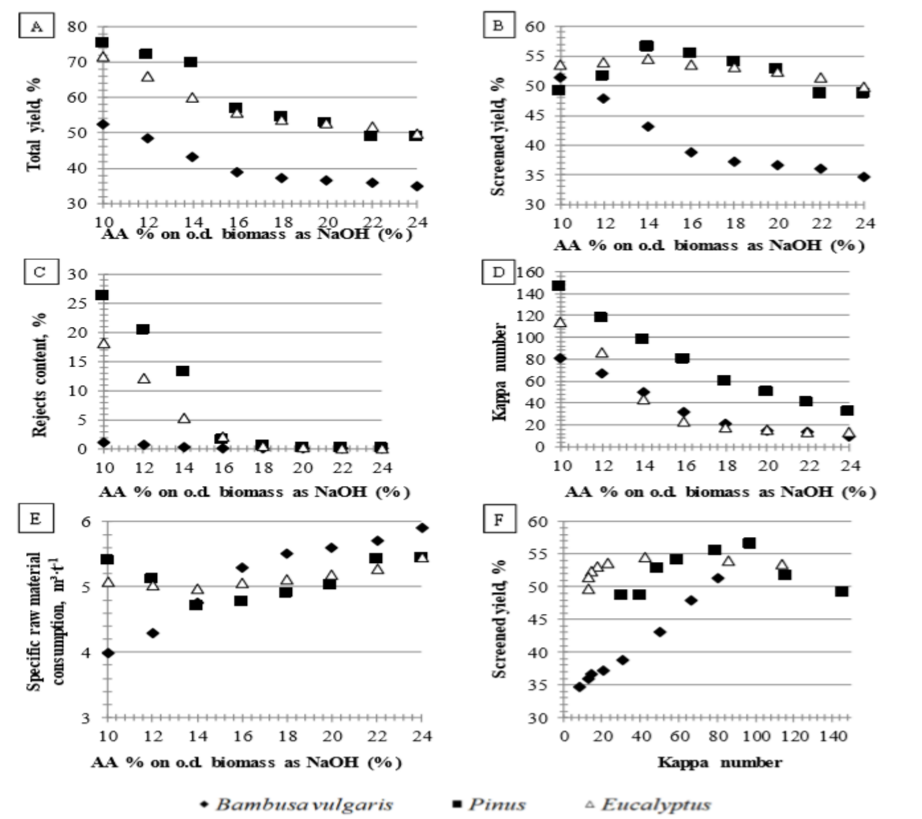

Figure 2: Total yield (A), Screened yield (B), Rejects content (C), Kappa number (D), Biomass specific consumption (E) and the connection between screened yield and kappa number (F)

4. Conclusion

From the past study, it can be concluded that this research's objective has been achieved. The first objective to review paper making from bamboo as a paper product is a success

The second objective is also successfully achieved to review the chemical analysis and fiber characterization of bamboo fiber. The chemical properties were reviewed according to the TAPPI and ISO standard test method. The results showed that average bamboo had cellulose around 50 to 55 percent. The bamboo had a high ash content (2.20 %), mainly silica, and low content for lignin (25.50 %).

Lastly, the third objective also successfully concludes and suggests the optimum pulp and paper properties from bamboo. From the reviewed for chemical pulping process it can be suggested that the kraft pulping with 18 percent of active alkali had the optimum properties of pulp and paper. The value of kappa number was around 20.03 percent, screen yield 44.40 percent and reject yield 0.31 percent. Meanwhile the optimum value for burst around 5.60 $kN.m^2/g$, tensile 5.763 (Nm/g)/10.

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References

[1] Aripin, A. B. M. (2014). Potential Of Non-Wood Fibres For Pulp And Paper-Based Industries. December.

[2] Rhett, A.B. (2005). Malaysia. Retrieved on November 24, 2012 from http://news.mongabay.com/2005/1228malaysia.html#hesukM8SbEkD1L7D .99

[3] Ashori, A., Harum, J., Yusoff, M.N.M., Wanrosli, W.D., Wanyunus, W.M.Z. and Dahlan, K.Z.M. (2004).TCF bleaching of kenaf (Hibiscus cannabinus) pulp for papermaking applications. Journal of Tropical Forest Science, 16(4), 463 - 471.

[4] Hammett, A. L., Youngs, R. L., Sun, X., & Chandra, M. (2001). Nonwood fiber as an alternative to wood fiber in China's pulp and paper industry. Holzforschung, 55(2), 219– 224. https://doi.org/10.1515/HF.2001.036

[5] Deniz, I., Okan, O. T., Serdar, B., & Şahin, H. İ. (2017). Kraft and modified kraft pulping of bamboo (Phyllostachys bambusoides). Drewno, 60(200). https://doi.org/10.12841/wood.1644-3985.224.05

[6] Rusch, F., Ceolin, G. B., & Hillig, É. (2019). Morphology, density and dimensions of bamboo fibers: A bibliographical compilation. Pesquisa Agropecuaria Tropical, 49(2013). https://doi.org/10.1590/1983-40632019v4955007

[7] LIESE, W.; TANG, T. K. H. Properties of the bamboo culm. In: LIESE, W.; KOHL, M. (Eds.). Tropical forestry, bamboo: the plant and its uses. Hamburg: Springer, 2015. p. 227-256.

[8] NAYAK, L.; MISHRA, S. P. Prospect of bamboo as a renewable textile fiber: historical overview, labeling, controversies and regulation. Fashion and Textiles, v. 3, n. 2, p. 1-23, 2016.

[9] LIESE, W. The structure of bamboo in relation to its properties and utilization. In: International Symposium On Industrial Use Of Bamboo, 1., 1992, Beijing. Proceedings Hamburg: Hamburg University, 1992. p. 96-100.

[10] Chang, F., Wang, E. I., Perng, Y., Chen, C., & Chang, F. (2013). Effect Of Bamboo Age On The Pulping Properties Of Bambusa Stenostachya Hackel. 47, 285–293.

[11] Lipp-Symonowicz, B., Sztajnowski, S., & Wojciechowska, D. (2011). New commercial fibres called 'bamboo fibres' - Their structure and properties. Fibres and Textiles in Eastern Europe, 84(1), 18–23.

[12] Imadi S.R., Mahmood I., Kazi A.G. (2014) Bamboo Fiber Processing, Properties, and Applications. In: Hakeem K., Jawaid M., Rashid U. (eds) Biomass and Bioenergy. Springer, Cham. https://doi.org/10.1007/978-3-319-07641-6_2.

[13] Bonfatti Júnior, E. A., Lengowski, E. C., Sulato de Andrade, A., Venson, I., Klock, U., Da Silva Júnior, F. G., Gonçalez, J. C., & Bolzon de Muñiz, G. I. (2019). Bamboo kraft pulping. Advances in Forestry Science, 6(4), 791. https://doi.org/10.34062/afs.v6i4.8361.

[14] Tripathi, S. K., Mishra, O. P., Bhardwaj, N. K., & Varadhan, R. (2018). Pulp and papermaking properties of bamboo species melocanna baccifera. Cellulose Chemistry and Technology, 52(1–2), 81–88.