YIELD STUDY OF ACACIA HYBRID USING ORGANOSOLV PULPING AND THEIR RELATIONSHIP WITH HANDSHEET PROPERTIES

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FACULTY OF SCIENCE AND NATURAL RESOURCES
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ABSTRACT

This study was made on pulp production from the fast growing plant, *Acacia* hybrid. The total yield, screened yield, rejected yield, Kappa number, and fibre morphology of organosolv *Acacia* hybrid pulp and Kraft pulp were determined. This study aimed to focus on the effect of the varied concentration of organic solvent towards the pulp yield and its relationship with Kappa number and pulp yield as well as comparison between organsolv pulp and Kraft pulp. Uniform-sized chips were taken to undergo pulping in a digester with five different concentrations of ethanol, 50%, 60%, 70%, 80% and 90% (v/v) with 10% of 1 M sodium hydroxide as catalyst. All chips were digested in a temperature-controlled digester with constant amount of water added and temperature of 185 °C with the duration of three hours cooking time and correspond pressure 1.1-1.2 MPa. It was observed that increasing of ethanol concentration has led to pulp yield and viscosity increment while decreased in Kappa number. Screened yield of 90% ethanol concentration showed 44.19% which was higher compared to Kraft pulp yield. These increments showed a significant difference at $p \leq 0.05$. Also, mechanical strength for tensile, burst, and folding of both non-beaten pulp and beaten pulp increased gradually with ethanol concentration from 50% to 90%. However, tear index decreased. The overall result showed that organosolv pulp properties were at par value as Kraft pulp properties.

ABSTRAK

KAJIAN PENGHASILAN PEMULPAAN ORGANOSOLV ACACIA HYBRID DAN HUBUNG KAITNYA DENGAN SIFAT-SIFAT KERTAS

Kajian ini telah dijalankan untuk menghasilkan pulpa daripada pokok Akasia. Jumlah penghasilan pulpa, hasilan penapisan pulpa, hasilan penolakkan pulpa, nombor kappa, dan morfologi serat bagi pulpa Akasia daripada proses organosolv pulpa dan Kraft pulpa telah ditentukan. Kajian ini bertujuan untuk memberi tumpuan kepada kesan kepekatan pelbagai pelarut organik terhadap hasil pulpa dan hubung kaitnya dengan nombor Kappa dan hasil pulpa serta perbandingan antara organosolv pulpa dan Kraft pulpa. Saiz cip kayu yang seragam telah diambil untuk menjalani prosess pemulpaan dalam mesin pencernaan dengan lima kepekatan etanol, 50 %, 60 %, 70 %, 80 % and 90 % (v/v) dengan 1 M natrium hidroksida sebanyak 10% sebagai pemangkin. Semua cip kayu yang telah dimasak dalam digester suhu terkawal dengan jumlah air yang ditambah secara konsisten dan suhu 185 °C dalam tempoh tiga jam masa memasak dan tekanan yang sesuai, 1.1-1.2 MPa. Adalah diperhatikan bahawa peningkatan kepekatan etanol telah membawa kepada peningkatan hasil pulpa dan kelikatan manakala pengurangan dalam nombor Kappa. Hasil pulpa bagi kepekatan etanol 90 % adalah 44.19% iaitu lebih tinggi daripada hasil Kraft pulpa. Peningkatan ini telah menunjukkan perbezaan yang signifikan pada $p \leq 0.05$. Kekuatan mekanikal kertas bagi kertas biasa dan kertas pemukulan meningkat secara perlahan apabila kepekatan etanol meningkat. Walau bagaimanapun, indeks koyakan. Keputusan keseluruhan menunjukkan ciri-ciri organosolv pulpa adalah setanding dengan Kraft pulpa.

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ASTM	American Society for Testing and Materials
AQ	Anthraquinone
Cm	Centimetre
CSF	Canadian Standard Freeness
Dbh	Diameter at breast height
FRIM	Forest Research Institute Malaysia
G	gram
H_2SO_4	Sulphuric acid
kg	Kilogram
kPa	Kilopascal
kV	Kilovolt
$KMnO_4$	Sodium permanganate
cPs	Centipoise
ISO	International standards
L	Litre
M	Molarity
mm	millimetre
min	minute
mg	miligram
ml	millilitre
mPa	Megapascal
O.D	Oven dry
N	Normality
NaOH	Sodium hydroxide
$Na_2S_2O_3$	Sodium thiosulfate
SAFODA	Sabah Forestry Development Authority
SEM	Scanning Electron Microscope
SPSS	Statistical Product and Service Solution
TAPPI	Technical Association of the Pulp and Paper Industry
˚C	Degree Celsius
%	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The industry of pulp and paper has been developed extensively since century ago and has emerged as an effective manufacturing sector in economic and social development throughout the world. Over million tons of paper has been consumed in Asia from the total of 109.4 Million Metric Tons in 2000 to 178.1 Million Metric Tons in 2010 to 250.7 Million Metric Tons in 2020 and to 323.7 Million Metric Tons in 2030 (RISI, 2012). Increasing of pulp and paper consumption has led to substantial research and development in pulping method mainly to mitigate air and water pollution, to reduce odorous emission, save energy consumption, increase the yield of pulp and ameliorate the physical and mechanical properties of paper.

Pulping is one of the most essential processes to form paper. It is a process which involves mechanical, semi-chemical or chemical treatment of breaking down lignin bonds within the wood structure to form fibrous mass, also known as pulp. This process is also known as delignification in some researches. Chemical pulping is among the most promising methods since it is able to produce higher yield and stronger pulp compared to those using semi-chemical and mechanical treatment. Statistic revealed that the world chemical pulps are mostly produced by the Kraft pulping process (Sridach, 2010). However, the pressure appeared to the environmental regulations on emissions of sulphur dioxide, suspended solids and wastewater pollution (UNEP, 1997). These environmental disadvantages have brought forth a more environmental friendlier pulping process referred as organosolv pulping.

Pulp and paper industry has emphasised on pulp yield production due to its benefit in generating profit to the industry. Besides that, high pulp yield production is required in order to fulfil the demand of the consumers. Pulp yield can be affected by many factors including wood species, wood anatomy, pulping chemistry, mill digester systems, cooking temperature, chip size, chip quality, Kappa number and many other sub-factors (MacLeod, 2007). In order to increase pulp yield, research has been continued to improvise the method of pulping especially in the area of pulping chemistry and Kappa number relationship using different species of hardwood and softwood. This study has emphasised in the usage of different concentrations of ethanol as organic solvent in the pulping process to evaluate on the yield of pulp produced.

Thus far, fast growing plantation species such as *Acacia mangium* is one of the most common plants used as raw material in pulp and paper industry in Sabah, Malaysia. However, research has shown that *Acacia* hybrid can be another alternative to *Acacia mangium.* It produced higher pulp yield compared to *Acacia mangium* and *Acacia auriculiformis* mainly because it contains higher composition of holocellulose content. Previous study stated that *Acacia auriculiformis* has the highest percentage of extractives which was 5.96% followed by *Acacia mangium 5.38%* and *Acacia* hybrid has the lowest percentage of extractives which was 2.9% (Yahya *et al.,* 2010). This is also the reason which *Acacia* hybrid was chosen as the raw material for this study.

1.2 Justification

Organic solvent particularly ethanol are considered as desirable solvent since previous study had proven that addition of ethanol in soda pulping is able to increase pulp yield while reducing Kappa number and screening rejects (Akgul and Tozluoglu, 2010). It has been the most frequently used solvent in organosolv pulping research for more than 100 years. Moreover, ethanol is easily penetrated through the structure of wood which leads to uniform delignification (Muurinen, 2000). It also act as an additive in mechanical pulping to reduce the use of energy and appeared to be a potential solvent in pretreatment process which enhance the efficiency of wood hydrolysis (Aravamuthan *et al.,* 2002). In caustic soda pulping, ethanol was added to improve delignification process which reduced the surface tension of the pulping liquor, hence causes penetration of ethanol into the wood chips to breakdown lignin component and prevent it from condensing (Muurinen, 2000). Kleinert (1940) revealed that ethanol was able to protect cellulose during delignification of cotton treated with water and ethanol solvent of various concentration.

Approximately 90% of wood was used extensively to produce virgin fibre pulp (Feng and Alen, 2001). Most of the wood pulp obtained from either hardwood or softwood. However, increasing in pulp and paper consumption has caused shortage in raw material. Therefore, it is important to find an alternative fibre source from fast growing plant. *Acacia* hybrid is one of the examples of fast growing plant that gaining over many species for commercial pulpwood production due to its morphology characteristic, physical properties and mechanical properties. It has the potential to produce high pulp yield and fix atmospheric nitrogen through symbiosis of the acacia's root with nitrogen fixing bacteria in the soil which improve the soil condition at the same time (Jahan *et al.,* 2007). Furthermore, it assists in reafforestation and act as a carbon stock to overcome the pressure of environmental problems (Kim *et al.,* 2008).

Another concern besides environmental issue is the pulp yield since there is a lack in the usage of raw material especially in wood. High pulp yield with low Kappa number and screened rejection are the most preferable outcome in pulping. Conventional Kraft pulping however did not convince for high pulp yield instead most of the organosolv pulp resulted in higher yield than the conventional Kraft or sulphite pulping. According to Xiao *et al.* (1999), *Eucalyptus cilriodora* chips were cooked in 8% of NaOH and 50% ethanol at 453 K for four hours and result shown that screened pulp yield was as high as 65%. Moreover, there were many studies on different species using ethanol as organic solvent had resulted in high yield (Muurinen, 2000). Therefore, it is which this study was done to emphasise on pulp yield produced using organosolv pulping method.

Organosolv pulping has been well established in laboratory scale whereby there are various organic solvents and catalysts being used in organosolv pulping. Most prominent organosolv processes are such as Kleinert, Alcell, MD Organocell, Organocell, SODA, ASAM, ASAE, NAEM, ester pulping, phenol pulping, Acetocell, Milox, and Formacell (Sridach, 2010). However, in this study, ethanol was selected as organic solvent and NaOH as the catalyst. Comparison was made between organosolv pulping and Kraft pulping since Kraft pulping is the most applied process to produce chemical pulps. Besides that, fast growing plants are rarely used as raw material in pulping as most research has been focusing on the use of non fibre resources. This study will then contribute to the industry and researchers in improvising the end product produced by the cooking condition applied in this study.

1.2 Objectives

This study was conducted based on the following objectives:

1. To determine and to compare the maximum pulp yield of *Acacia* hybrid and Kappa number using different concentrations of ethanol.
2. To compare physical and mechanical properties of handsheet between Kraft pulping and organosolv pulping.
3. To compare handsheet properties of beaten pulp and non-beaten pulp.

CHAPTER 2

LITERATURE REVIEW

2.1 Description of *Acacia* hybrid wood

This sub topic provides background of *Acacia* hybrid wood, explains the physical, mechanical and chemical properties of *Acacia* hybrid.

2.1.1 Introduction of *Acacia* hybrid wood

Acacia hybrid is under the family Fabaceae and subfamily Mimosoideae. In terms of its botanical characteristic and morphology, *Acacia* hybrid is a medium size tree which able to reach the height in ranged of 8 to 10 m and a diameter at breast height (DBH) of 7.5 to 9.0 cm in two years (Figure 2.1). The traits of the flower colour, leaf shape, size, pod, bark and wood density are the combination of those *Acacia mangium* and *Acacia auriculiformis* (Bueren, 2004).

Acacia is widely distributed throughout the tropics and subtropics mainly in Australia and Pacific. It was reported that the natural hybridisation between the *Acacia auriculiformis* as the male parent and *Acacia mangium* as the female parent was found in Sabah, Malaysia in the late 1970s. It was distributed where the mean annual temperature is 12°C to 35 °C and annual precipitation of 1200 to 1850 mm (Bueren, 2004).

Figure 2:1: Three years old *Acacia* hybrid's plantation.

Source : Bueren (2004).

2.1.2 Physical properties

Acacia hybrid is able to identify from its distinct heartwood and sapwood whereby the heartwood is dark brown while the sapwood is light brown in colour. It is categorised as a hard and dense wood. The grain was fine and interlocked while its texture was moderately smooth. Moreover, it obtains fine lines of parenchyma which imitates the presence of growth rings (Rokeya *et al.,* 2010).

Emphasis has been given to *Acacia* hybrid since it posses good characteristics especially in growth rate and wood properties such as wood density, moisture content and fibre length which are very much attributed to the pulp and paper productions. Rokeya *et al.* (2010) reported that *Acacia* hybrid has the highest specific gravity and volumetric shrinkage which were 0.56 and 9.71 respectively when compared to *Acacia auriculiformis* which were only 0.61 and 8.01 and *Acacia mangium*, 0.52 and 7.01. Moreover, Kha (1996) stated that the wood density of *Acacia* hybrid was 0.455 g/cm³ which considered higher than *Acacia mangium* .