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Pulpability of SAP Stained Vascular Bundles of Elaeis Guinensisfrond (OPFB) for Paper Production

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Abstract- This research finding was aimed at determining the pulp and paper potential of sap stained oil palm fronds rachis vascular bundles (OPFB) using an ecofriendly alkaline peroxide pulping. Alkaline peroxide pulping (APP), which combines both pulping and brightening actions into a single process, was attempted on sap stained oil palm frond rachis vascular bundles (OPFB). After the maceration of the raw samples, a total of two hundred fibres were randomly examined under light microscope and the mean values of their morphological dimensions were recorded. The obtained data was utilized to calculate the felting rate, flexibility coefficient, Rigidity coefficient, Runkel index and rigidity index. The effects of these properties on paper strength were equally evaluated. The mean fibre length values obtained was 1.30mmfor OPFB while the mean fibre diameter of the biomass was 17.62µm. and the Runkel ratio for OPFB was 0.48. The chemical composition determinations were carried out in five times replicate while the mean was determined using the SPSS statistical package. The result of the chemical analysis of the raw plant materials revealed high α-cellulose content of 66.17% and a low Klason lignin content of 19.1% compared to those of some hardwoods and softwoods. The mycological examination of the sap stain microorganism confirmed it as Aspergilliusflavus which was successfully removed at the early stage of pulping. Base on the investigation of the fibre properties and chemical composition of this sap stained oil palm frond rachis with respect to its suitability or otherwise as the fibrous raw materials for pulp production, pulping of the biomass was carried out and characterized. The results of this research finding indicate that the anatomical properties of the biomass compared favourably with soft and hard wood globally used for pulp and paper.

Index Terms- Oil Palm frond rachis vascular bundles; Sap stained Microorganism; Aspergilusflavus; Alkaline Peroxide Pulping.

I. INTRODUCTION

In Malaysia, due to conducive ecosystem, there about 4000 species of fungi in existence, of which sap stain are very prominent (Lee et al., 2012). Sap stain fungi are common indoor and outdoor stain fungi and surface moulds common in tropical countries like Malaysia. This is due to prevailing conducive hot-humid Climatic conditions prevalent in such geographical region. Sapstain caused by fungi results in considerable qualitative loss of wood products problem on wood species in Malaysia.Wood parasitic fungi are categories into three: (1) moulds and stain fungi that normally do not degrade lignified cell walls and derive their nutrition from contents of dead cells, (2) soft rot fungi capable of limited enzymatic degradation of lignified cell-walls and (3) decay fungi with high ability to degrade wood causing either brown or white rot (Subramanian, 1983). Due to lack of adequate storage facility to meet the massive generation of this waste biomass, these microorganism thrive except if the wood moisture content is reduced to less than 24% (Florence, 1991). Staining fungi Increase wood permeability by degradation of ray parenchyma cell walls (Scoggins & Bridgen, 2014).The use of preservative is suggested to prolong the service life of this biomass. Recent reports on health hazards and environmental pollution caused by the use of chemical preservative have suggested the adoption of biological control of sapstain fungi (Benko, 1988; Bernier Jr et al., 1986; Susi et al., 2011). Economic advantage of these biomasses will reduce the problem of disposal and the thriving activities of sap stain microorganisms in the ecosystem.

Increase in industrialization, urbanization, and population growth has led to increasing production and consumption of paper and paper products. This development has led to the diminishing in the forest resources and in effect has led to production of enormous quantities of industrial waste biomass that may cause environmental and health hazards. There is a global drive towards the concept of reverse logistics which is pivoted on the principle of waste to wealth is seen as a means of remediating resource exhaustion and environmental degradation (Khor & Udin, 2013).Malaysia is presently the second world leading producer of palm oil subsequent to Indonesia. In the year 2008, about 51 million tons oil palm frond (OPF) was generated from oil palm plantations whose economic potential has not been fully tapped and are still left to rotten away through the actions of the various types of microorganism in which sap stain is very prominent (Goh et al., 2010). OPF has been reported to contribute 70% of overall oil palm waste (Eng et al., 2004). This lignocellulosic waste materials have also been reported to undergo biorefinery processes for the isolation of their fibres used for paper making, cellulose derivatives and other chemical (Dahlan, 2000; Lim & Ibrahim, 2013; Rodríguez et al., 2010; Rosli et al., 2004a; Wanrosli et al., 2007; Wanrosli et al., 2004; Zainuddin et al., 2011). OPF is a lignocelluloses biomass that is made up of the leaflets, the rachis, the petiole mid-rib and spines Fig 1 (Hosseinpour et al., 2014; Mirmehdi et al., 2014; Zahari et al., 2003) and has been found to be cheap source of cellulose (Lim & Ibrahim, 2013). The physico-chemical composition of lignocelluloses biomass was reported to dependent on the various geographical location, age, weather and different types of soil materializations(Jalonen et al., 2014).The discolouration observed on the OPFB, was caused by sapstain fungi as a result of superficial growth of mould fungi which secrets some coloured melanin-based pigments in the cell to create a conducive environment for their growth. Although sap stain fungi do not have any significant effect on the strength properties of the predated biomass, they are reported to live on the nutrients from the components of the protoplasm in the parenchyma cells(Mauseth, 2012). In Malaysia, the concept of green revolution is pursued through reverse logistics and green product design which employ green supply chain management practices that are being implemented to demonstrate firm's commitment to environmental sustainability. Various governmental agencies are coming out with different environmental regulations while on the other hand academics and researchers are contributing solutions and suggestions in different country contexts. This has led to the search for the suitability of some of these microbial invested lignocelluloses in various industrial endeavours.

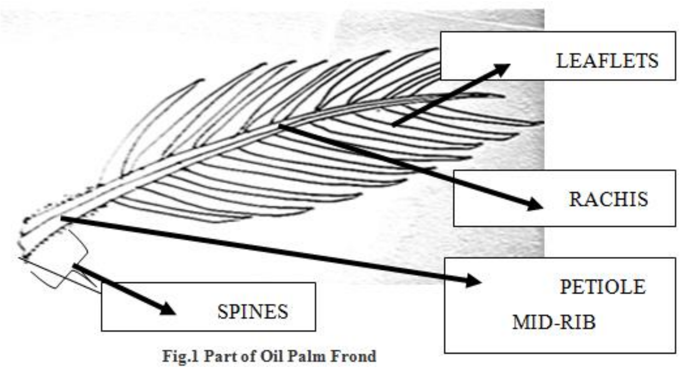


Fig.1 Part of Oil Palm Frond

Since the introduction of alkaline Peroxide Mechanical Pulping (APMP) by Andritz Sprout-Bauer in 1989 , which is consider as an upgrading of the Chemi-Thermo-Mechanical Pulping (CTMP) process (Y. Dermawan & Ghazali, 2011)), various researchers have been investigating this eco-friendly pulping protocols with respect to its general acceptability. Despite the success attempts recorded in the application of APMP on Empty fruit bunches EFB, Ghazali and co-workers reported another success achieved in using a pulping methodology with modified working principle of APMP on EFB (A Ghazali et al., 2009). The simplified modified technique called Alkaline Peroxide Pulping (APP) recorded good pulp product of EFB pulp and improved paper quality as obtained in the APMP-EFB pulping at the laboratory level. Since the report on the use of APP which unlike the APMP eliminates the multiple stages of chemical impregnations and refining stages, its application in research and development have been successfully done using the new APP pulping technique work(Y. M. Dermawan, Ghazali, et al., 2014; Y. M. Dermawan et al., 2011; Y. M. Dermawan, Kamaluddinm, et al., 2014; Arniza Ghazali et al., 2012; M. Rosnah et al., 2010). This paper reports the paper properties, fibre characteristics and the chemical properties of the sap stain raw materials with respect to its suitability in the pulp and paper industries.

II. MATERIALS

The leaf shredded oil palm frond Mid-rib was supplied from BalikPulau Malaysia. The rachis was cut off its spined petiole midrib and the fibrous strands of the rachis which consisted of vascular bundles was extracted and kept in plastic bag in the paper laboratory at the Universiti Sains Malaysia (USM)**.** Three days after the extraction, the growth of the blackish microorganism was being noticed which later grew to cover the whole extracted strands in the plastic bag after a period of thirty days. The sodium hydroxide and hydrogen peroxide of Merck Schuchart, Germany was procured from local chemical vendors.

III. METHOD

Mycological investigation of sap stain fungi

The identification of the sap stain microorganism which was suspected to be fungi was explored using the basic mycological cultivating procedure describe by Samson, Robert et al.,2010 to identify the microorganism. The laboratory work was carried out at the Plant Pathology Lab. A at the school of Biology.grams of the potato agar powder was suspended in 500ml of cold distilled water .The mixture was heated to boiling to dissolve the agar completely, with continuous stirring to enhance proper mixing of the agar. The agar was allowed to cool to about 45°C (temperature checked with help of the sterilized lab thermometer). The cooled agar mixture was pour into sterile Petri plates about 5mm deep and allowed to set. Once the gel hardened, they were refrigerated at the microbiology lab at the environmental division of the school of industrial technology. The plates were stored upside down with potato dextrose agar in upper half of plate. This was done to prevent condensation from dripping down and contaminating the agar growing surface. This was followed by direct inoculation of the sap stained biomass on the prepared agar. The strip of the vascular bundle with fungi growth was streaked directly on the agar. The inoculated plate was incubated in the incubator at the school of Biology at the temperature of 28^{0}C. After the 4^{th} day of inoculation the inoculums had started growing. The microorganism species was re inoculated in a prepared agar plate to get a pure culture. This took about three days. The isolated specie was prepared on a slide by smearing. The smeared slide was covered with slide cover, heat fixed and viewed under the Olympus light microscope model CX41, attached to an X-Camera model U-TUO,5XC-3 Japan Camera at the magnification of X40 attached to a computer at the school of Biology.

Fibre biometry and morphology characteristics

The ground OPFB was macerated using the method as described by Franklin's (1945) and reported by(Frimpong-Mensah, 2007).This involved the introduction of the sample biomasses cut to about 5cm in a conical flask with 1:1 H_2O_2/CH_3COOH solution mixture and heated at 70^{o}C and the solution kept with intermittent shaking until all the fibres have been fully separated. The separated fibres were sieved using frighted glass crucible, washed thoroughly with distilled water and mounted on a slide for the determination of the fibre dimensions. The fibre dimensions were measured, using a projected Olympus light microscope (BH-2) coupled to a CCD camera connected to a computer at reasonable magnifications of 4X for fibre length and 40X for fibre diameter, lumen diameter and cell wall thickness respectively. For this, 200 fibres were randomly measured and the average was taken. The fiber length, fiber diameter, and lumen width were measured the average fiber dimensions were calculated and then the following derived indexes were determined:

Elasticity coefficient (%) = $\frac{Lumen\ diameter}{fibre\ dimeter}\ X\ 100$

Rigidity coefficient (%) = $cellwall\ \frac{thickness}{fibre\ diameter}\ X\ 100$

Runkel index = $\frac{2\ X\ cellwallthickness}{LumenDiameter}$

Felting ratio (%): $\frac{Fibre\ length}{Cellwall\ thickness}\ X\ 100$

Slenderness ratio = $\frac{fibrelength}{fibrediameter}$

Chemical composition

The raw materials were analysed for holocellulose, α-cellulose, Klason lignin, ash, alcohol–benzene extractable, cold and hot water and 1% soda soluble, in accordance with the applicable TAPPI standards: T-203-0S-61, T-222, T-221, T-204, T-257 and T-212, respectively in five replicates and the average recorded.

Alkaline peroxide impregnation

The oil palm fronds rachis vascular bundles was washed thoroughly, dried and milled. The OPFB was soaked in distilled water at 70 ºC for 30 min, in order to remove extractives component(Y. Dermawan & Ghazali, 2011). At the end of the dewaxing process, the biomass particles were dewatered by pressing at 15 psi. Alkaline peroxide liquor was prepared in the ratios:- 1:1.5 of sodium hydroxide to hydrogen peroxide by weight percentages. The reaction was allowed to proceed for 10mins. 20mins, 30mins., 40mins.,50mins. and 60mins. at 70 ºC, after which the biomass was again pressed at 15 psi.

Refining and making of handsheets

Refining was conducted with a Sprout Bauer Refiner, to allow fibrillation. The screened fibres obtained were made into handsheets, according to (TAPPI, 1996).

Paper testing

A total of six sets of handsheet with 10 sheets per set were prepared for the testing. The physical testing of the hand sheet was carried out in the paper testing instrument laboratory of USM with respect to the grammage and thickness while the mechanical testing conducted in the study involved:- burst index (TAPPI 403), tensile index (TAPPI 494), and tear resistance index (TAPPI 414). The optical testing included brightness, opacity and scattering coefficient of the handsheets (TAPPI 452).

IV. RESULT AND DISCUSSIONS

Identification of the sap stain microorganism

The identification of the microorganism was based on the macro- and micro-morphology identification on high powered light microscope (Barry et al., 2009). This was done by viewing the prepared slide under the light microscope for the identification of mycelium and hypha arrangement. The Isolates selected were observed to have green colour colony grown evenly on PDA medium which was incubated at 37°C for 4 days. The macromorphic image of the isolate revealed a yellowish to light green colony (Fig.3).

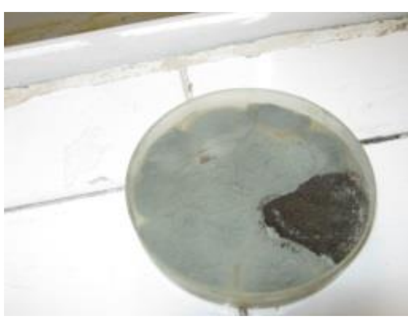


Fig.2:Macromorphic image of fungi isolate

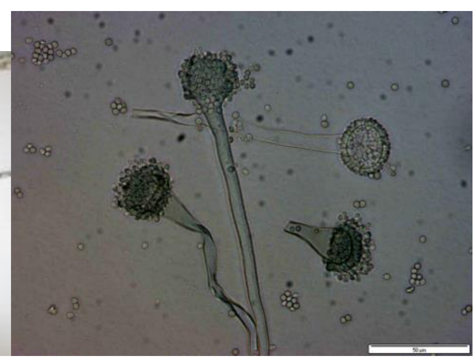


Fig.3: Micromorphic image of fungi isolate

The light microscope revealed round-shaped vesicles (Fig.2), conidiophores somewhat greenish nodes and conidia spore round and light green (Fig.3). Based on the results of cell morphology observed, these isolates belong to the group of Aspergillus sp. that have the same characteristics, namely globular vesicles, conidiophores shaped translucent yellowish green, semi conidia spore round to round-shaped light green(Samson et al., 2010; Yunasfi, 2008).

Fibre characteristic of OPFB

The study of the morphological properties of the raw fibre is necessary since fibres retain most of their original structure during pulping and papermaking. This could serve as a predictive measure of the quality of the proposed paper that is intended. Despite the presence of the sap stain, the biomass is characterized with anatomical properties with the reported properties as obtained in a normal Oil palm biomass (Table 1). The average fibre length of 1.3mm OPFB is comparable with what obtained from Gmelina (0.8mm-1.3mm); Eucalyptus (0.7mm-1.3mm); Rice straw (0.5mm-1.0mm); Bagasse (1.0mm-1.5mm) etc. which are being used commercially for pulp and paper production, as reported by (Atchison, 1995). The large lumen width of 11.64µm is expected to have positive impact on the beating process of the pulp. The observed large cellwall thickness of OPFB from Table1 is expected to positively affect the bursting strength, tensile strength and folding endurance of paper while the relatively low value as indicated in table 1 could be attributed to the presence of the sap stain microorganism that have predated on the sap content of the biomass. Runkel ratio of less than one, indicates that cellulose obtained from this fibre is suitable for production of paper(Eroglu H. Bektas I & Tutus, 2010; Xu et al., 2006).

Table 1: Fibre characteristic of Oil Palm Biomass (%)

	Fibre length (mm)	Fibre diameter (µm)	Lumen width (µm)	Cellwall thickness (µm)	Runkel Ratio	Coefficient of Elasticity	Rigidity Index	Slenderness Ratio	references
OPFB	1.30	17.62	11.64	2.3	0.48	64.28	66.62	84.25	Present work
OPF (strand)	1.59	19.7	-	3.95	-	-	80.61	-	(Wan Rosli & Law, 2011)
OPEFB	0.99	19,1	-	3.38	-	-	55.43		(Wan Rosli & Law, 2011)
OPT (whole)	1.32	35.3	-	4.4	-	-	20.72	-	(Husin et al., 1985)
OPT (strand)	0.96	29.6	-	4.8	-	-	42.64	-	(Khoo & Lee, 1991)
Acacia Mangium	0.9	22.3	2.9	-	-	-	22	-	(Law K.N., 2000)

The generally acceptable value for slenderness ratio of papermaking fibres are more than 33(Xu et al., 2006). From tables 1 the slenderness ratio of OPFB is higher which an advantage as pulp and paper material is.

The flexibility ratio that give quality writing paper are categorize under the following conditions(Bektas et al., 1999; Istas et al., 1954).:-

a. High elastic fibres having elasticity coefficient greater than 75.
b. Elastic fibres having elasticity ratio between 50 to 75.
c. Rigid fibres having elasticity ratio between 30 to 50.
d. High rigid fibres having elasticity ratio less than 30.

Agreeing to the above classification, flexibility coefficient of OPFB is 84.25 indicates the property of the fibre with high elasticity.

Chemical composition of OPFB

The characteristics high chemical contents of the oil palm biomass are reflected in the general results obtained in table 2. The various diversity observed in the composition, could be attributed to a lot of factors which include the geographical location of the biomass, and the position within the plants(Jalil A.A. et al., 1991; Khoo & Lee, 1991). The high lignin in OPFB is a major characteristic of the oil palm biomass due to it protective and strength properties in the plant. Despite the presence of the sap-stain the values still fall within what is obtainable in some hard wood and soft wood(Tsoumis, 1991). The oil palm frond is the photosynthetic portion of the oil palm plant hence the observed high α-cellulose content of the biomass is not unconnected with the strategically positioning of the OPFB on the oil palm frond system. This high α-cellulose content is an advantage with respect to the strength property when used for pulp and paper(Khalil et al., 2007). The low extractive content with respect to the other non affected biomass could be attributed to the presence of the sap stain microorganism. Sap stain microorganism has been reported to remove some resinous materials in the extractives which cause pitch problem in pulping process (Farrell et al., 1997) which is a relative advantage as paper material.

Table 2: Chemical composition of Oil Palm Frond (OPF) (%)

	A/B Solubility(%)	1% Solubility	Holocellulose (%)	α-Cellulose(%)	Lignin(%)	Ht water solubility(%)	Ash (%)	references
OPFB	5.56	22.51	78.39	66.17	19.1	9.88	3.72	Present work
OPF (whole)	5.2	36.4	67.4	49.6	19.4	17.5	4.9	(Jalil A.A. et al., 1991)
OPF (whole)	7.12		73.85		16.37			(Hassan et al., 1991)
OPF (strand)	7.33		76.15		16.59			(Hassan et al., 1991)
OPF	5.50	36.1	78.6		18.5	14.1	3.7	(Hosokawa et

(strand)								al., 1989)
OPEFB	3.7	14.5	82.4		18.8	7.5	1.3	Law (Law et al., 2007)
EFB	0.9	17.2	70.0	42.7	17.2	2.8	0.7	(Khoo & Lee, 1991)
OPT (whole)	9.8	40.2	45.7	29.2	18.8	14.2	2.3	Husin et al.,1985
OPT (strand)	1.2	19.5	71.8	45.8	22.6	2.5	1.63	Khoo&Lee 1991
Acacia Mangium	4.8	16.4			25.6	6.16		Law & Wan Rosli 2000
OPF	4.5		83.5	49.8	20.5		2.4	Abdul Khalil et al., 2006
Soft Wood	0.2-8.5		60-80	30-60	27-37		<1	Tsoumis 1996
Hard Wood	0.1-7.7		71-89	31-64	14-34		< 1	Tsoumis 1996

The low alkaline and hot water solubility of the rachis in table 2 indicates minimum biology oxygen demand (BOD) and chemical oxygen demand (COD) is expected to be generated in the mill effluence(Wan Rosli & Law, 2011)..

Influences of Alkaline Peroxide impregnation on the sap stain Biomass

Generally it was observed that at the end of the impregnation prior to refining process the black stain deposited on the biomass by the sap stain microorganism disappeared resulting in good pulp which was washed, dried and weighed to get the yield. This was due to the effect of the pre-treatment soaking in the distilled water at high temperature. At high temperature the microorganism must have died. At this condition the biomass had absorbed the water, swell up to enhance the impregnation of the alkaline peroxide which also increased the surface area of the biomass for the chemical penetration that remove the black stain and the residual spores of the microorganism. The absence of the microorganism was later confirmed after the culturing of the pulp. It was observed that the inoculated plates did not show any sign of microbial growth after seven days of incubation. This confirmed the effective elimination of the presence of the microbe by the adopted alkaline peroxide (APP) pulping protocol.

Influences of Cooking Variables on the yield

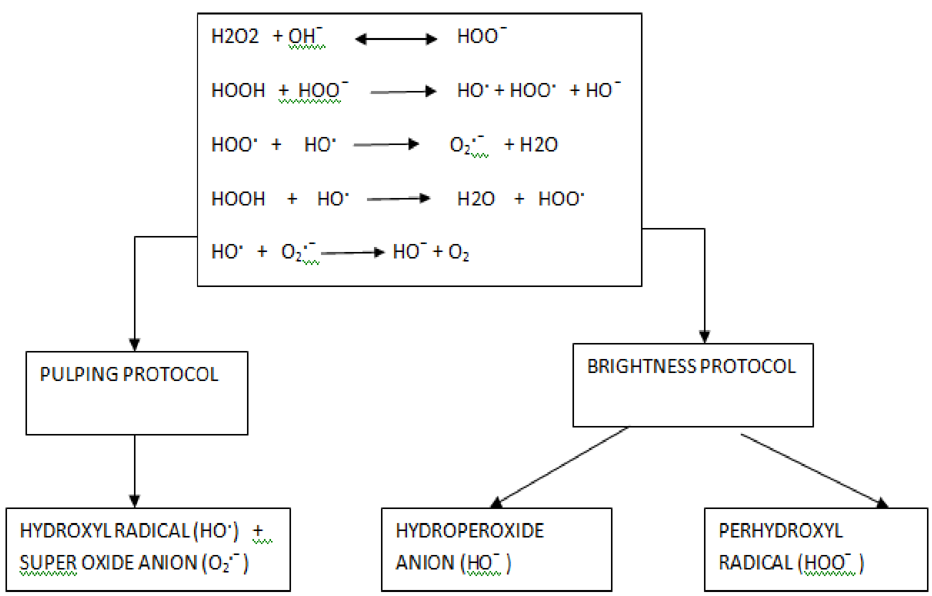
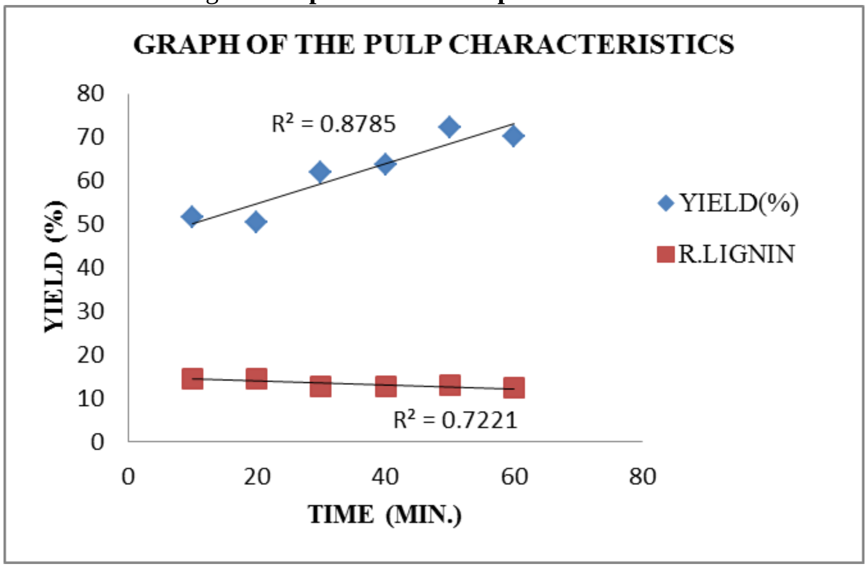


Fig 4: MECHANISM OF ALKALINE PEROXIDE PULPIN

The characteristic of the pulp from alkaline peroxide pulping was shown in Fig.5. While there was gradual increase in the yield with time the reverse was observed with respect to the residual lignin percentage. In the presence of sodium hydroxide, and absence of any stabilising agents like diethylenetriaminepentaacetic acid (DTPA), ethylenediaminetetraacetic acid (EDTA) etc hydrogen peroxide is unstable and readily decomposes to generates more active radicals such as the hydroxyl radicals (HO·) and superoxide anion radicals (O_2·) (fig.5).These intermediate products are capable of causing delignification and bleaching effect of the lignocelluloses biomass. This dual role of hydrogen peroxide in delignifying and bleaching is summarized as shown in Fig. 5 (Gould, 1984, 1985).

Fig 5**:- Graph of the AP Pulp characteristics**



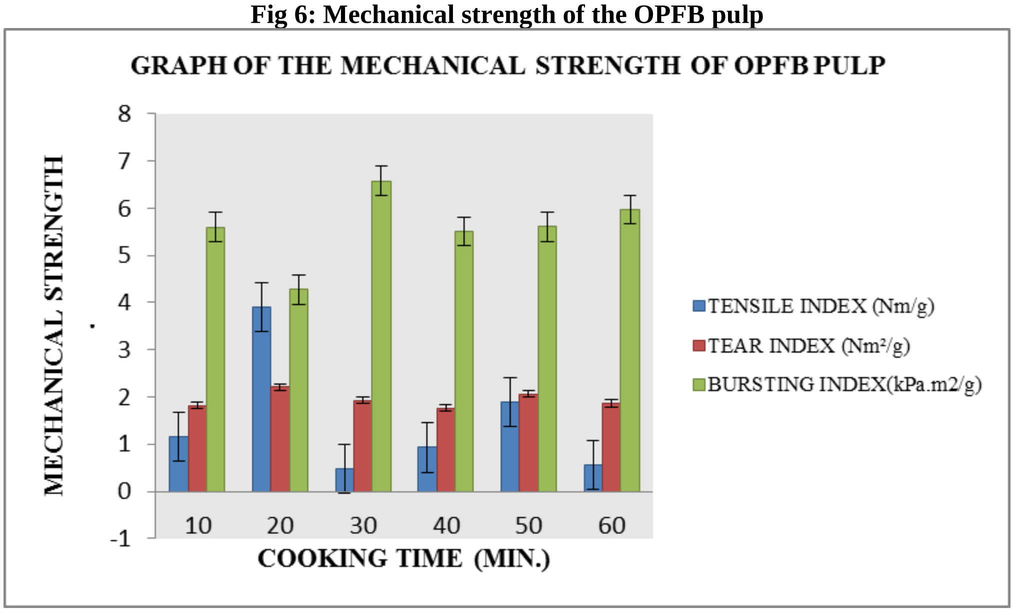
Approximately 50% of delignification and dissolution of the hemicelluloses at 25°C in an alkaline solution of 1% H_2O_2 have been reported (Gould, 1984). Apart from activating the decomposition of hydrogen peroxide, sodium hydroxide has powerful swelling ability for lignocellulosic materials which paves easy penetration for the generated radicals in the alkaline peroxide premix. Delignification reaction in lignocelluloses biomass involve the cleavage of the phenolic α–O–4 linkages, cleavage of non-phenolic β–O– 4 linkages, and removal of residual lignin fractions, either by cleavage of carbon– carbon linkages or by carbohydrate degradation, releasing lignin-carbohydrate fractions, which are mainly oxidised into aliphatic carboxylic acids (Buxton et al., 1988). These active hydroxyl radicals and superoxide anion radicals (Fig.5), participate actively in the delignification of lignocelluloses at room temperature.

Paper Testing

MECHANICAL PROPERTIES

The result of the mechanical indices of the paper produced from Alkaline peroxide pulp of OPFB was graphically displayed in Fig 6 showing the error bar with standard error**.** Tensile test results reflect the intimate structure of paper and the properties of its Individual fibres. The dimensions and strength of the individual fibers, their arrangement, and the extent to which they are bonded to each other are all important factors contributing to test results.

Fig 6: Mechanical strength of the OPFB pulp



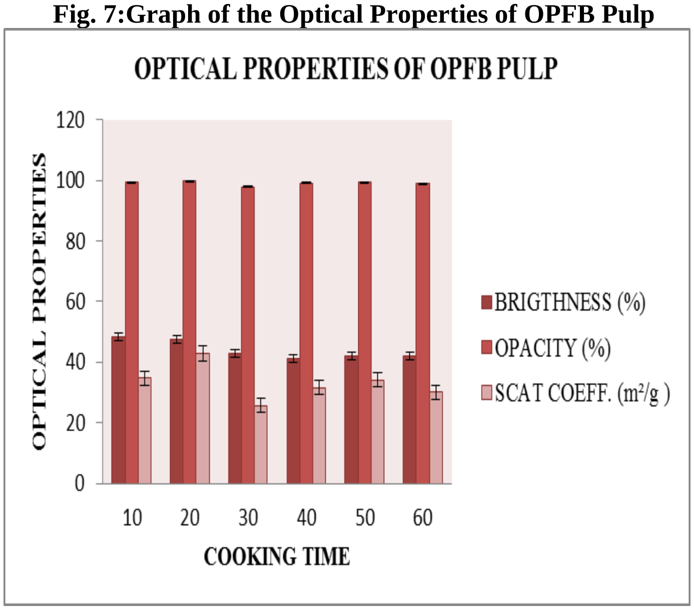
The result reflects the synergistic effect of the alkaline peroxide charge on the tensile index with time at higher concentration. The graph shows general increase in the tensile index with time. This is as a result of possibility of higher delignification and generation of hydrogen bonding which enhances the interfibre bonding as time increases. Tensile strength can also be influence by the mechanical abrasion of the impregnated fibre by the refining process, this is due to the generation of both internal and external fibrillations.

Among the factors affecting the Bursting strength is, degree of bonding, individual fibre bonding, individual fibre strength, fibre length and fibre coarseness (Foelkel, 2007). Like what is obtainable in tensile index the result reflects the synergistic effect of the alkaline peroxide charge on the burst index The trend agrees with the report by earlier researchers that the burst Index has good and positive correlation with the tensile and tear Index (Ramírez et al., 2009) .

Tearing resistance is an empirical property which is dependent upon fibre length and the bonding strength between the fibres. Tear strength depends on the interfibre bonding which depends on the strength of the hydrogen bonding in the paper formed. Wan Rosli and co-workers (2004a) reported that tear index is a function of both fibre strength and fibre interbonding which indirectly is dependent on the degree of delignification; the more lignin is removed, the more hydrogen bonding can occur, hence the stronger is the paper.

OPTICAL PROPERTIES

Fig. 7:Graph of the Optical Properties of OPFB Pulp



Handsheets prepared from alkaline peroxide pulping are generally characterized by high brightness and opacity as shown in fig 7 displaying the error bar with standard error. The main effects of hydrogen peroxide and alkali charge on brightness (measured as ISO) is shown in Fig 7. The alkaline peroxide bleaching of non-wood fibres have been widely reported (Hosseinpour et al., 2014; Mustajoki et al., 2010; M. Y. Rosnah et al., 2010).The alkali peroxide charge was the most influential factor in relation to the brightness of oil palm frond Rachis pulp which is in tandem with the earlier report(Wanrosli et al., 2005). The mechanism of alkaline peroxide brightness consists of four major kinetic steps which include: adsorption of alkaline peroxide intermediate to the pulp fibre walls; removal of chromophoric chemical reaction on the fibre wall; release of “light” organic products formed from the fibre wall; and oxidation chain reduction of the cleaved organic substances(Liu, 2003). The brightness involve multiple cite mechanism. The mechanism involve the generation of very active intermediate namely:- hydroxide anion and perhydroxyl radical (Fig. 4) which take part in the brightness mechanism. The generatedneuclophilichydroperoxide anion reacts with chromophoric substances in the cell-wall such as quinones, cinnamaldehyde, and ring-conjugated ketones in the lignin molecule converting them to non chromophoric species during the alkaline solution(Dence, 1996; Pan et al., 1998). The reaction which is site specific occurs simultaneously to achieve the ISO brightness and is not reversible(Liu, 2003). .

The scattering coefficient of a pulp is a measure of surface area and fibre bonding. Higher surface area means higher level of unbounded fibres which translates to higher scattering coefficient. Larger surface area could be attributed to the presence of fine fibres which could contribute to large surface area if not bonded to the fibre. Reduction in scattering coefficient is desirable for the improved bonding and strength properties. The general high opacity observed is an indication of good printability of the paper formed from the OPFB pulp.

V. Conclusion

From this study, we found that the growth of the sap stained fungi which was Aspergillius flavus on the OPFB does not have significant adverse effect on the pulp and paper properties of the biomass. The physicochemical properties of the vascular bundles from the frond of oil palm tree that deem fit to be used in papermaking are assessed and compared with other raw materials to see its viability. The initiative for total use of lignocellulosic oil palm biomass will definitely help in forest conservation and in building a sustainable future through effective environmental practices and solves the waste disposal crisis in oil palm growing countries. This information is necessary as it will help in encouraging the use of such biomass in pulp and paper industries. It is important to produce a pulp of acceptable brightness with a significant dissolution of lignin but a minimal degradation of cellulose. APP is aa high-yield pulping method, which is capable of producing pulp of acceptable brightness with a significant dissolution of lignin and minimal degradation of cellulose.

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