International Journal of Oil Palm, **2** (1): 19 - 23, June 2001

RESEARCH PAPER

SODA PULPING AND HYPOCHLORITE BLEACHING OF OIL PALM EMPTY FRUIT BUNCH

Rushdan Bin Ibrahim
Wood, Paper & Coatings Technology, School of Industrial Technology,
Universiti Sains Malaysia, 11800 Penang, Malaysia.

ABSTRACT

The oil palm empty fruit bunch (EFB), a solid waste has got good potential to be used as raw material for pulp and paper industries. EFB has to undergo pulping and bleaching process to produce a white pulp for paper making. In this work, EFB was pulped by soda and soda-AQ pulping processes. The pulp was then bleached by hypochlorite and alkaline extraction. The soda pulping process produced a higher total yield but the soda-AQ pulping produced a higher screened yield. The EFB total yield was comparable to other commercial non-wood species but lower, when compared to Malaysian hardwood species. Hypochlorite bleaching and alkaline extraction increased the brightness of soda-AQ pulp much better than soda pulp. The rates of changes in brightness between stages and pulps were different.

Key words: Alkaline extraction (E), anthraquinone (AQ), brightness, *Elaeis guineensis,* lignin, yield.

INTRODUCTION

Malaysia is a net importer of most paper products except for toilet/tissue paper (Mat, 1997). The imported paper and paper products have caused considerable depletion of Malaysian foreign exchange. To overcome this problem, the Malaysian Government and UNDP/FAO Asia Pacific Forest Industries Development Group encouraged investments in pulp and paper industry (Mat, 1997; Thang, 1989).

One of the important factors in establishing a pulp industry is the availability of fibrous material either from wood and/or non-wood sources. Oil palm solid waste, a non-wood fibre source, has a good potential to be used as a raw material for pulp and paper industries (Khoo and Lee, 1991; Lubis *et al.*, 1994). The application of oil palm solid waste as raw material for pulp and paper is extremely promising because the future demand for paper in Malaysia is expected to be enormous.

Most non-wood pulp is produced by soda pulping process (Atchison, 1987a; Minor, 1996). The pulping chemical used in the soda pulping process is sodium hydroxide (NaOH), an alkali. The alkali causes the lignin molecules to fragment into smaller segments, which dissolve as phenolate or carboxylates (Smook, 1992). The effect of soda pulping on species was variation in pulp yield and the amount of lignin left in pulp. Anthraquinone (AQ) was discovered to accelerate soda pulping and consequently increased the yield and decreased the amount of lignin left in pulp (Holton, 1977).

To produce white paper, pulp has to be bleached. Bleaching makes pulp whiter and brighter to the eye. Bleaching is a chemical process applied to pulp to increase its brightness by lignin removal. Unbleached pulp is coloured due to the absorption of visible light by the presence of residual lignin, a highly coloured substance. There are more than ten types of bleaching chemicals. The chemicals commonly used for bleaching of pulp are oxidants, alkali, and sodium hydrosulphite (Reeve, 1996). Most non-wood pulps are bleached by using hypochlorite either as a single stage, three-stages or four-stages of bleaching (Atchison, 1987b; Bhargava, 1987; Kim Oanh *et al.*, 1999; Kraft, 1963; McGovern *et al.*, 1987; Misra, 1987; Wierdermann, 1987, Zheng *et al.*, 1999). Hypochlorite oxidizes, decolourises and solubilises the lignin (Reeve, 1996).

Pulp brightness is one of the parameters in monitoring bleaching progress. The degree of brightness is in a range of 0% to 100%. Zero percent is very dark pulp and 100% is very white pulp. Different types of bleaching chemicals, stages and sequences are used in producing different degrees of pulp brightness. The objectives of this study were to determine the effect of alkaline pulping (soda and soda-AQ) and bleaching (hypochlorite and sodium hydroxide) on oil palm empty fruit bunches (EFB).

MATERIAL AND METHODS

Two batches of 200 g. (dry weight) of EFB were pulped by soda and soda-AQ processes. The pulping conditions employed were 170°C of maximum cooking temperature, 90 min. duration to reach maximum temperature, 90 minutes. duration at maximum temperature, 1:8 of EFB to liquor ratio and 20% of amount of NaOH of EFB (dry weight). 0.1% of amount of AQ of EFB (dry weight) was added to soda-AQ pulping process. At the end of each digestion, the softened EFB was washed on a screen, disintegrated for five min. in a hydropulper and screened by Somerville fractionators. The total pulp yield was calculated as the sum of the screened pulp yields and the sieves. Kappa number was determined according to TAPPI Test Methods T 236 cm-85 (TAPPI, 1994).

In bleaching, the soda and soda-AQ pulps were bleached by four different stages, single stage and multistage: hypochlorite (H), H and sodium hydroxide (E), HEH and HEHE. The hypochlorite bleaching (H) conditions employed were 30°C of temperature, 60 min. of time, sodium hypochlorite concentration of 3% of EFB (dry weight) and consistency of 3%. The alkali extraction (E) conditions employed were temperature of 30°C, 60min. duration, sodium hydroxide concentration at 1% of EFB (dry weight) and consistency at 3%. The pulp was washed thoroughly between bleaching stages. Pulp brightness was measured according to TAPPI Standard T 452 om-92 (Anonymous, 1994).

RESULTS AND DISCUSSION

The pulp yield and brightness of EFB pulp were obtained by soda pulping and hypochlorite bleaching (Table1).

Table 1 : Pulping and bleaching of oil palm empty fruit bunches

Pulping		
	Soda	Soda-AQ
Total Yield (%)	44.74	36.98
Screened Yield (%)	20.74	30.69
Sieves (%)	24.0	6.29
Kappa No.	15.33	7.20
Absorption coefficient (cm^3/g)	9.62	8.11
Bleaching		
Brightness before bleaching (%)	23.9	26.1
Brightness after hypochlorition (H) (%)	62.8	57.1
Brightness after H and alkaline extraction (E) (%)	64.2	67.2
Brightness after HEH (%)	65.9	68.4
68.4Brightness after HEHE (%)	67.0	73.0

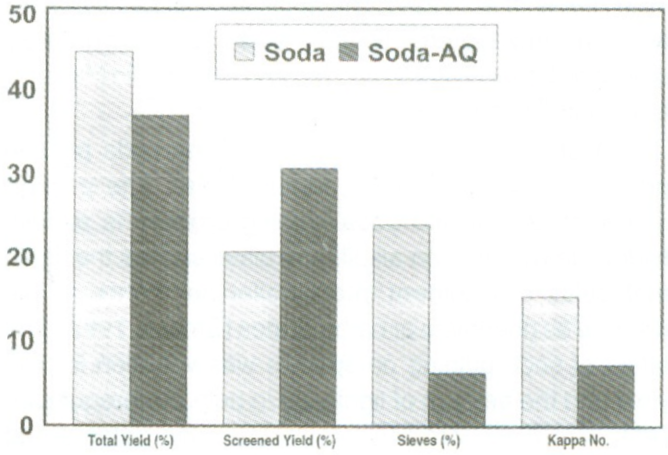
Pulp Yield

The total yield of soda process was higher than soda-AQ process by 7.76%. Soda-AQ had a higher screened yield and a lower reject of 9.95% and 17.71% respectively (Fig.1). The result was in a range when compared to report of Mott *et al.* (1996) but was lower compared to that of Wan Daud *et al.* (1998). Compared to kraft pulping, this result was lower (Khoo and Lee, 1991). When compared to other non-wood species, EFB soda's total yield was higher than rice straw and papyrus but was lower than esparto, reeds, bagasse, jute, abaca, kenaf and sisal and was equal to bamboo and flax (Atchison, 1987a). Whereas, when compared to Malaysian hardwood species, EFB soda's total yield was lower than that of *Azadiracta excelsa* (Rushdan, 1999). The differences in yield are due to the nature of species, their chemical and physical characteristics - that affect the topochemical and diffusion processes during the pulping process (Minor,1996).

In soda pulping process, the main objective of NaOH in white liquor is to dissolve out the lignin from the middle lamella that binds the cellulose fibres together, thus separating the fibres. Besides dissolving the lignin, NaOH also dissolves some carbohydrates. There is a relationship between the amount of NaOH consumed and the amount of fibrous material dissolved (Bryce, 1980; Rushdan, 1999). Since AQ accelerated the pulping rates, the quantity of wood component was increasing. Consequently the total yield of soda-AQ was decreasing (Holton, 1977). An addition of AQ on EFB reduced the total yield by 7.76% on pulp.

Mott *et al.* (1996) found that soda-AQ process was more efficient than soda process and they got soda-AQ yields in the range of 45.13 to 49.33%. Akamatsu *et al.* (1987) found that the addition of a low quantity of AQ (< 0.15%) can increase the pulp yield but adding more than 0.15% will decrease the pulp yield (Mohd Nor *et al.*, 1989). When 0.1% AQ was added to kraft pulping of oil palm trunk,

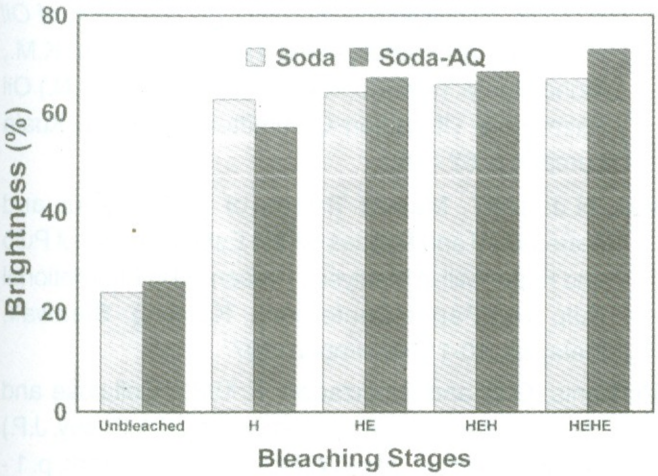
Fig.1: Pulp yields and kappa number of EFB soda pulps



the yield increased by 0.9%. The addition of AQ in soda pulping of *Acacia mangium* decreased its yield and lignin content by 3% and 51% respectively (Rushdan, 1999). This difference was due to the natural chemical and physical properties of species (Minor, 1996).

The screened yield increased by 9.95% and sieve decreased by 17.71% as the AQ was added (Fig.1). The increase in screened yield and the decrease in sieve were due to the increase in lignin dissolved. As more lignin was dissolved, more fibres were separated and fewer fibres were bonded together. Kappa number and light-absorption coefficient can measure indirectly, the quantity of lignin in pulp. The Kappa number and light-absorption coefficient were decreasing when AQ was added (Tab. 1, Fig.1). The light-absorption coefficient measures the presence of coloured component in the pulp. Cellulose is a white solid material but lignin is a coloured material (McGinnis and Shafizadeh, 1980).

Fig.2: Bleaching of FFB's soda pulps



Brightness

The brightening of pulp in hypochlorite bleaching is due to the destruction of lignin derivatives formed from the original lignin in the preceeding pulping or bleaching stages. The main light-absorbing substances in pulp are derived from the lignin of the original fibrous material. Bleaching chemically reduces the concentration of light absorbing constituents so that paper reflects more light. These light-absorbing substances are oxidized and reduced to make them soluble in an aqueous solution in order to remove them from the pulp (Histed *et al.*, 1996).

The brightness of pulp increased as the stages of bleaching were increased (Fig. 2). Soda pulp brightness increased from 23.9% to 67%, an improvement of 43.1%. But soda-AQ pulp's brightness increased from 26.1% to 73%, an improvement of 46.9%.

The improvement in the rate of brightness between pulps is not equal. This difference is due to the nature of residual lignin of soda and soda-AQ pulps (Herbst, 1963). Several types of chemical reactions taking place during soda and soda-AQ pulping processes affect the structure of the lignin remaining in the fibres at the end of the process (Gellerstedt, 1996). The AQ produces a different chemical composition in pulp (Minor, 1996). AQ added to kraft pulping tends to preserve hemicellulose content in pulp (Farrell *et al.*, 1996). The first stage of bleaching has the highest of brightness improvement, 38.9% and 31.0% for soda and soda-AQ respectively because the first stage has the highest rate of delignification (Berry, 1996; Reeve, 1996).

A single application of chemical has a limited effect in brightness improvement. Multistage application of bleaching chemicals can provide much greater benefits. Interstage washing, which removes dissolved impurities, is partially responsible for improvement in the extent and efficiency of bleaching. Multi-stage sequence takes advantage of the different action of each chemical and provides synergy in bleaching.

Hypochlorite oxidizes and fragments the lignin but, because it was carried out under acidic conditions, only part of the degraded lignin dissolves. The role of extraction is to remove the lignin made potentially soluble by the previous acidic oxidizing stage and to reactivate the pulp for further oxidation (Berry, 1996). The extraction improves the soda-AQ brightness more than soda. The brightness of soda is improved by 1.4% after HE stages and 1.1% after HEHE stages whereas the brightness of soda-AQ is improved by 10.1% after HE stages and 4.6% after HEHE stages. All the reactions that occurred in extraction are affected by carryover from the previous stage (Berry, 1996).

CONCLUSION

The following conclusions may be drawn from the study performed on soda pulping and hypochlorite bleaching of oil palm empty fruit bunches:

1. Soda pulping produces a higher total yield but soda-AQ pulping produces a higher screened yield.
2. Kappa number and absorption coefficient of soda-AQ pulp are lower than soda pulp,
3. The EFB total yields are comparable to other commercial non-wood species but lower, when compared to Malaysian hardwood species.
4. Hypochlorite bleaching and alkaline extraction increase the brightness of soda-AQ pulp better than soda pulp,
5. The rate of changes in brightness between bleaching stages and pulps are different. The first stage of

bleaching has the highest change of brightness.

ACKNOWLEDGEMENTS

I express my gratitude to USM for financial support, Sabutek (M) Sdn. Bhd for providing the EFB samples and Mr. Azli Sulid and Mr. Zulhisham Mohamad for collecting the data.

REFERENCES

Akamatsu, I., Mohammad, H., Hirosi, K. and Abdul Halim, H. 1987. Industrial utilization of oil palm (*Elaeis guineensis*) by-products I. Kraft-anthraquinone pulping of oil palm empty fruit bunches. *Cellulose Chem. Technol.*, **21**: 67-75.

Anonymous. 1994. *TAPPI Test Methods 1994-1995*, TAPPI Press, Atlanta.

Atchison, J.E. 1987a. Data on non-wood plant fibers. In: *Pulp and Paper Manufacture Volume 3: Secondary Fibers and Non-wood Pulping*, 3rd edition. (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 4 - 16.

Atchison, J.E. 1987b. Bagasse. In: *Pulp and Paper Manufacture Volume 3: Secondary Fibers and Non-wood Pulping*, 3rd edition (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 23 - 70.

Berry, R. 1996. Alkaline extraction. In: *Pulp Bleaching: Principles and Practice*, (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 291 - 320.

Bhargava, R.L. 1987. Bamboo. In: *Pulp and Paper Manufacture Volume 3: Secondary Fibers and Non-wood Pulping*, 3rd edition, (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 71 - 81.

Bryce, J.R.G. 1980. Alkaline Pulping. In: *Pulp and Paper*. Vol. 1. 3rd edition, (Ed. Casey, J.P.), John Wiley and Sons, New York, p. 377- 491.

Farrell, R.L., Viikari, L. and Senior, D. 1996. Enzyme treatments of pulp. In: *Pulp Bleaching: Principles and Practice*. (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 363 - 377.

Gellerstedt, G. 1996. Chemical structure of pulp components. In: *Pulp Bleaching: Principles and Practice*, (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 91 - 111.

Herbst, J.H.E. 1963. The chemistry of hypochlorite bleaching. In: *The Bleaching of Pulp*, TAPPI Monograph Series No. 27, TAPPI Press, Atlanta, p. 116 - 129.

Histed, J.A., Sandel Jr., L.F. and Hurst, M.M. 1996. Hypochlorite and hypochlorous acid bleaching. In: *Pulp Bleaching: Principles and Practice*, (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 395 - 410.

Holton, H. 1977. Soda additive softwood pulping: a major new process. *Pulp and Paper Can.*, **78**(10): 19-24.

Khoo, K.C. and Lee, T.W. 1991. Pulp and paper from the oil palm. *Appita*, **44**(6): 385-388.

Kim Oanh, N.T., Bengtsson, B.E., Baetz Reutergardh, L., Hoa, D.T., Bergqvist, P.A., Broman, D. and Zebuhr, Y. 1999. Persistent organochlorines in the effluents from a chlorine-bleached kraft integrated pulp and paper mill in Southeast Asia. *Arch. Environ. Contam. Toxicol.*, **37**: 303 - 309.

Kraft, F. 1963. Bleaching practices for different pulp types. In: *The Bleaching of Pulp*, TAPPI Monograph Series No. 27, TAPPI Press, Atlanta, p. 219 - 241.

Lubis, A.U., Guritno, P. and Darkano. 1994. Prospects of oil palm solid wastes based industries in Indonesia. In: *Proc. third National Seminar on Utilisation of Oil Palm Tree and other Palms 1994*, (Eds. Poh, K.M., Mohd Nor M.Y., Khoo, K.C. and Nurulhuda M.N.) Oil Palm Fibre Utilization Committee Malaysia, Kuala Lumpur, p. 62 - 69.

Mat, H.J. 1997. Market Trends of Pulp, Paper and Paperboard and Policies on the Establishment of Pulp and Paper Mill in Malaysia, Presented in International Pulp and Paper Conference. Kuching, Sarawak, Malaysia. 10-11 November 1997.

McGinnis, G.D. and Shafizadeh, F. 1980. Cellulose and Hemicelluloses. In: *Pulp and Paper*, (Ed. Casey, J.P.) Vol. 1. 3rd edition. John Wiley & Sons, New York, p. 1 - 38.

McGovern, J.N., Coffelt, D.C., Hurter, A.M., Ahuja, N.K. and Wiedermann, A. 1987. Other Fibers. In: *Pulp and Paper Manufacture Volume 3: Secondary Fibers and Non-wood Pulping*, 3rd edition (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 110 - 121.

Minor, J.L. 1996. Production of unbleached pulp. In: *Pulp Bleaching: Principles and Practice*. (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 25 - 57.

Misra, D.K. 1987. Cereal Straw. In: *Pulp and Paper Manufacture Vol. 3: Secondary Fibers and Non-wood Pulping*, 3rd edition (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 82 - 93.

Mohd. Nor, M.Y., Khoo, K.C. and Lee, T.W. 1989. Properties of sulphate and soda-AQ pulps from oil palm trunk. *J. Trop. For. Sc.*, **2**(1): 25-31.

Mott, L., Abi Salem, Arifa Sulaiman and Ross Matthews. 1996. Optimizing the pulping of oil palm empty fruit bunches material. In: *Oil Palm Residues: Progress Towards Commercialisation* (Eds. Harun, J., Mohmod, A.L., Abdul Aziz, A., Khoo, K.C., Mohd. Yunus, N.Y., Md. Tahir, P., Abood, F., Mohd. Yusof, M.N. and Husin, M.), OPTUC, Kuala Lumpur, p 131 - 140.

Reeve, D.W. 1996. Introduction to the principles and practice of pulp bleaching. In: *Pulp Bleaching: Principles and Practice.* (Eds. Dence, C.W. and Reeve, D.W.), TAPPI Press, Atlanta, p. 1 - 24.

Rushdan, I. 1999. Soda pulping of *Azadiracta excelsa* wood. Presented in CFFRP 99 - Utilisation of Plantation Timber*: Sentang,* FRIM, Kepong, Selangor, 20 April 1999.

Smook, G.A. 1992. *Handbook for Pulp and Paper Technologist* 2nd edition, Angus Wilde Publication, Vancouver, 419 p.

Thang, H.C. 1989. *Pulp and Paper Industries in ASEAN Region.* Asia Pacific Forest Industry Development Group, RAS/86/048 Fields Doc. No. 12, Kuala Lumpur, 92 p.

Wan Daud, W.R., Law, K. and Valade, J.L. 1998. Chemical pulping of oil palm empty fruit bunches. *Cellulose Chem. Technol.,* **32**(1-2): 133-143.

Wierdermann, A. 1987. Reeds. In: *Pulp and Paper Manufacture Vol. 3: Secondary Fibers and Non-wood Pulping*, 3rd edition (Ed. Kocurek, M.J.), TAPPI Press, Atlanta, p. 94 - 121.

Zheng, M., Liu, P., Bao, Z. and Xu, X. 1999. Aspects of formation and degradation of polychlorinated dibenzo-p-dioxins and dibenzofurans. *Chinese Sci. Bull.*, **44** (14): 1249 - 1256.