CHAPTER 4

DISCUSSION

4.1 Preliminary processing

The oil palm leaflets, typical of monocotyledonous plants, comprise a mass of discreer vascular bundles embedded in parenchymatous tissue. It is this fibrous vascular tissue free from the embedding parenchymatous matter that provides the cellulosic fibres for pulp.

The parenchymatous matter is susceptible to fungal attack. In the early stage, the fungus attacks the food content of the parenchyma cells. The cell walls were not attacked but this could not be ruled out on prolonged exposure (Khoo, 1989).

Due to this, the leaflets were immediately cut up upon arrival and air-dried, then kept in sealed plastic bags to be stored indefinitely.

4.2 Density

The mean density of the midrib was 0.547 g/cc while that of the leaf blade was 0.241 g/cc. This is shown in Table 7. The generally low density values could be related to thin cell walls and it also indicates that shorter cooking times might be sufficient for the cooking liquor to penetrate the fibre strands (Yusoff *et al.*, 1984).

Chemical analysis

The results of the proximate chemical composition of il palm midrib and leafblade are given in Table 11. aring the data with those reported by Khoo and Peh) for Malaysian hardwoods, it is clear that the values the midrib are typical of Malaysian hardwoods except for her pentosans content. In comparison with some mono- ledonous species, the oil palm midrib contained lower and pentosans contents (0.7% and 25.7% respectively), e higher lignin content (24.5%) and comparable with s than to grasses or straws as shown in Table 10.

However, the very high ash, high alkali, alcohol- zene and hot water solubilities and low alpha-cellulose tent of the leaf blade as compared to the midrib, render nfavourable for papermaking. The very high ash (9.1%) ld affect the economy of any recovery process connected h pulping. The low alpha-cellulose content (24.1%), high kali solubility (51%) and high lignin content (30.3%) ld indicate a heavy chemical consumption combined with a pulp yield. All of these expectations were sequently confirmed from this study.

Morphological characteristics

Table 3 presents a comparison of the morphology of re from the different parts of the oil palm.

The similarity of the oil palm midrib fibre to low ity hardwoods is in having rather short length and atively thin walls. The midrib with thinner walls has potential as a pulping material since thin cell walls indicative of better general paper making properties. ers made from thin-walled fibres are expected to be dense well formed whereas those derived from thick-walled res are generally bulky with coarse surfaces. Thick-led fibres also adversely influence bursting strength, ile strength and folding endurance (Peh *et al.*, 1986).

The thin walled fibres of the midrib, with large lumen, a moderate coefficient of suppleness and based on the iteria of Istas *et al.* (1954), such fibres are expected to tially collapse (flatten), giving an elliptical cross-tional form, producing good surface contact between acent fibres and hence good fibre to fibre bonding. The Runkel ratio at 0.38 and moderate coefficient of pleness (72.0%) of the midrib would be expected to confer erage strength properties to pulps produced from it. wever, the high Runkel ratio (1.4) and low coefficient of ppleness (41.4%) would not favour pulping of the afblade. The high Runkel ratio indicates that the fibres fairly thick-walled while the coefficient of suppleness icate not only thick walls but also a rather narrow men. The fibres are expected to show only a small amount flattening in papermaking, which in turn gives a fairly ll surface contact and fairly poor fibre to fibre ding.

From the microscopic studies, the fibres of both the rib and leaf blade appeared as cylindrical cells with fine-pointed and gradually tapering ends. This can be n in Plates 3 and 4. The length of the midrib fibre 92 mm) is about twice that of the leaf blade (0.89 mm). diameter of the midrib fibre at 15.6 μ is larger than diameter of the leaf blade fibre (11.1 μ). The lumen of leaf blade (4.6 mm) is narrower compared to that of the rib (11.2 mm) while the cell walls of the midrib (2.2 mm) thinner than the cell walls of the leaf blade (3.2 mm). re was a large amount of non-fibrous matter present, tly consisting of vessel elements and parenchymatous ells especially in the leaf blades.

Since the midribs contain most of the fibres suitable r papermaking while the leaf blades consist of shorter and oken fibres and a greater proportion of non-fibrous ssue, it is reasonable to expect the leaflets if cooked hole, to give pulps of lower yield and strength haracteristics.

Pulping trials were conducted to determine the required nditions for achieving satisfactory results. A higher quor to material ratio was needed to pulp the leaf blades d the leaves (whole) than the midrib on account of the lky nature of the leaf blades.

When the leaves (whole) were pulped by the soda ess, the non-fibrous matter dissolved, giving a poor ld (9.3%) of pulp. This can be seen in Table 12. ndsheets were not made since the yield was very low. milarly, when the leaf blades were pulped by the soda cess, a low yield (9.9%) was obtained as in Table 13.

5 Soda pulping

Table 14 shows the results of the pulping trials of the rib by the soda process. It is apparent that the midrib not easily pulped by this process even up to an active ali (A.A.) of 18%.

Cooking below 17% A.A. was unfeasible as the low emical concentrations were not sufficient to complete the gestion and adequately delignify the material as shown by e high kappa numbers. This resulted in the hard pulps, or yields and high amount of rejects. This is also true f the leaf blades as can be seen in Table 13. Since the eld was very poor, handsheets could not be made from the oda pulp of the leaf blades.

Sulphate pulping

It is clear from Table 15 that the midrib could be ped by the sulphate process. An A.A. of not more than was sufficient to produce a pulp with a kappa number of 1. Cooking below 18% A.A. did not significantly affect yield but an A.A. below 15% was not feasible due to a degree of digestion at that chemical concentration as an by the high kappa numbers. A low yield (9.9%) was ined when the leaf blades were pulped by the sulphate ess as shown in Table 16. Only a set of handsheets d be made.

Table 17 gives the details of bleaching of the pulp ained from Cook 4 with a kappa number of 21.4. A yield 22% was obtained from the simple three stage (CEH) ching. There was an appreciable loss in yield of 8%.

NSSC pulping

Due to the bulky nature of the midrib, the liquor to d ratio was kept at 7:1 to ensure better liquor culation in the digester. The results of the NSSC ping properties are given in Table 18.

As expected, there was a general reduction in total ulp yield and a decrease in Kappa number with increasing emical concentration as shown in Figure 29. The material was not difficult to pulp as a chemical charge as low as 4%

oduced an acceptable pulp yield (60.7%), but it was cessary to increase the sodium sulphite concentration yond 12% since the Kappa number (117) remained high at at concentration (12%). However, even with a chemical arge of 16%, the Kappa number at 109 did not decrease much spite a large drop in yield to 52%. Considering the low eld and small improvement in Kappa number, it might not be rthwhile to pulp beyond 8% sodium sulphite concentration. e concentration of sodium carbonate was kept at 6% to hieve a non-acidic pH. This did not prove to be adequate Cook 10 when the low concentration of sodium sulphite ed (4%) could not provide the additional buffering action gainst the acids produced. Increasing the concentration of dium carbonate to 8% could raise the pH to a more sirable level.

.8 Pulp evaluation

Sulphate pulps

The results of the evaluation of the bleached and unbleached sulphate pulps are shown in Table 19. Their strength results are graphically presented in Figures 1 to 10.

A preliminary pulping trial of the leaf blades using an A.A. of 18% gave a very poor yield, hence only a set of handsheets were made. Since not only a set of handsheets could be made, graphical evaluation could not be produced. However, comparing the results with those of the sulphate pulp of the midrib at the same A.A. of 18% and beating, it can be seen that the values for the leaf blades are lower than that of the midrib.

Evaluation of the unbleached sulphate pulps of the midrib showed the pulps to have quite similar properties except in the tearing strength where Cook 4 with the lowest kappa number gave the best results. In fact, Cook 4 showed the best development of strength on beating. When this pulp was bleached, however, an overall drop in strength was clearly noted. Nevertheless, an unusual feature about this bleached pulp is that on beating, while the tearing strength remained practically constant, other strength values improved. Examination of the fibres showed that beating caused some changes to the cell wall structure but not much to the fibre length, thus explaining for the mild drop in tearing strength of the beaten pulps. This is especially so for the bleached pulp. Thus it could be inferred that these fibres were not easily shortened although the cell wall could be altered by beating. This is illustrated in Photomicrographs 5 to 9. In the bleached pulps, the tearing strength was retained down to a freeness value of 190 ml Csf, indicating little loss of fibre length.

4.9 Soda pulps

Results of the evaluation of the soda pulps are shown in Tables 20 and their strength results are depicted graphically in Figures 11 to 19.

With respect to the tearing strength of the soda pulps, the raw Cooks 6 and 7, especially the former which ahd the lowest kappa number, gave the poorest values. With low beating, Cook 8 had lower tearing stength than Cook 9, but on further beating at freeness less than 400 ml Csf, the tear improved and surpassed that of cook 9. Differences in other strength properties between the soda pulps were not so marked especially on beating as shown in Figures 12 to 19.

4.10 NSSC pulps

The full details of the NSSC pulp evaluation are given in Table 21. The strength properties are illustrated in Figures 20 to 28.

The NSSC pulp with the overall maximum strength, especially in tensile and bursting strength came from cook 13 (at 16% sodium sulphite) with a Kappa number of 109.

Cook 12 (at 12% sodium sulphite) showed a high tearing and bursting strength initially which dropped rapidly on beating. Cook 10 (at 4% sodium sulphite) and cook 11 (at 8% sodium sulphite) were not easy to beat as the freeness dropped to only 280 ml Csf even after 90 minutes of beating. Cooks 10 and 11 showed a slight increase in overall strength properties on beating with the exception of tearing strength.

Insufficient chemical charge could be a reason for inadequate dispersion of the fibre bundles which led to the low strength properties of cook 10 and 11 (4% and 8% sodium sulphite respectively).

Cook 13 (16% sodium sulphite) was the easiest to beat with a rapid development for all strength properties except for a slight drop in tear. Strength development on beating was fast whereby after an hour of beating, the freeness dropped to 200 ml Csf. In fact, strength development was already noticeable after the first beating point.

Generally, the strength properties of the NSSC pulps from cooks 10 to 13 indicate a general improvement accompanied by a drop in Kappa number with increase of chemical charge. However, the strength improvement at more than a chemical charge of 12% might not be sufficient to offset the additional expenditure of chemicals and the reduced pulp yields. Cook 10, at a low chemical charge of 4% and an average yield of 60.7% could be preferable to the other cooks.

From Figures 9 and 10, it can be seen that the freeness of the soda and sulphate pulps decreases as beating increases. The freeness of the NSSC pulps also dropped on beating but no clear trend was seen.

Prolonged beating causes the cellulosic fibre wall to gradually break up into extremely minute fibrils. It is this fibril formation that increases the retention of water (Technical Section of the British Paper and Board Maker's Association, 1949). Plates 5 to 9 illustrate this.

4.11 Comparison with sulphate pulps from oil palm trunk and empty fruit bunches (EFB)

From the work of Peh et al. (1976) and Khoo and Lee 986), it was found that pulping of the trunk and EFB uired prior to separation of the fibrous strands from the enchymatous tissue. The operation, although time-nsuming and requiring the use of auxiliary equipment was essary not only to prevent biological degradation but lso to produce cleaner and stronger pulps at a lower sumption of chemicals. The trunk was less messy to ndle compared to the EFB which had a faster rate of terioration.

Sulphate pulping of the EFB required higher chemical ncentrations than the trunk, although the yields of the mer were generally better. An A.A. of 16% was needed to duce bleachable pulps for the EFB, whereas an A.A. of 14% sufficient to produce pulps of bleachable grades for the nk. On bleaching, the loss in yield for both materials B (9.3%), trunk (9.7%)] was almost similar but the EFB a brighter pulp (90%) compared to the trunk (67%).

Higher chemical concentrations were needed to produce phate pulps of the midrib compared to both the trunk and probably due to the higher lignin content in the midrib. lds were generally lower, but on bleaching, the yield was her for the midrib than both the trunk and EFB and the ghtness was better than the trunk but lower compared to B.

The sulphate pulp from the trunk was easier to beat h a faster development of strength which was generally tter, especially in folding endurance to that of the responding pulp from the EFB. The only redeeming feature the latter was in having very good stretching property.

The sulphate pulp from the midrib was also easy to beat h a fast development of strength. Although the tensile dex and folding endurance were better than that of the unk, tearing strength and stretch of the midrib were far tter than the trunk.

Compared to the EFB, the sulphate pulp of the midrib as better in terms of tear and tensile index but the etch was superior in the EFB.

12 Comparison with NSSC pulps from oil palm trunk

From studies conducted by Yusoff (1985), it was found at the fibrous strands from the oil palm trunks were itable material for producing NSSC pulps of acceptable ength properties at low chemical charges of 4 to 10% ium sulphite and at short digestion times. Moderate pulp lds of 62 to 70% were obtained. Excessive addition of ium carbonate, up to 12% was required to achieve the non-aline condition in the cooking liquor.

The results also suggested that to achieve a Kappa mber of over 70, the amount of sodium sulphite used during estion should not be more than 6%. Apart from tearing ength, the pulps possessed good overall strength perties. Beating of the NSSC pulp gave rise to a fast elopment of strength properties, resulting in a high gree of inter-fibre bonding.

NSSC pulping of the midrib required higher chemical arges (4-16%) to produce moderate yields (52-60.7%) mpared to the low chemical charges (4-10%) for the trunk produce higher yields of between 62-70%. Perhaps the terence in cooking temperature (170°C for the trunk, 60°C for the midrib) affected the yields.

. . A chemical charge of up to 16% could only produce pulp kappa number 109, whereas for the trunk, 6% sodium phite was sufficient to produce a kappa number of above . Strength properties were generally better for the trunk n the midrib.

13 Comparison with pulps from oil palm petiole

From studies conducted by Joedidobroto (1982), it was nd that the chemical pulps from oil palm petiole had good ures.

Prior removal of the parenchyma tissues was necessary produce high yields of pulps. Pulping by the soda cess produced pulps with a rather high Kappa number (60) high screenings. Delignification was improved by the ition off a small amount of anthroquinone (0.15%). The ping properties of the pulps were comparable to those of phate pulps obtained from cooks at similar active charge 14% and sulphidity of 20%.

The strength properties of the pulps were quite similar those of pine sulphate pulp except for the low burst ues. The pulps gave breaking lengths close to 10 km, ch is rather high and similar to softwood pulps. The a process produced the weakest pulps. The paper strength operties of the petiole pulp could probably be compared with hardwood sulphate pulp.

From the morphological point of view, the length of the drib fibre (1.82 ± 0.55 mm) was not much different from at of the petiole [1.58 mm (periphery), 1.35 mm (inner ore]. The felting power of the peripherial fibres was 138 ile that of the inner fibres was 91. The felting power of midrib fibre was 116.3 . However, the Runkel ratio of midrib fibre at 0.39 was much smaller than both the pherial fibres (2.41) and the inner fibres (0.43). This ture could render the midrib more favourable in ermaking.

However, the chemical composition of the petiole was favourable than the midrib in terms of pulping. The her lignin content (24.5%) and alcohol-benzene solubility .5%) of the midrib would indicate a higher chemical sumption combined with a lower yield compared to the iole (18.8%, 6.5% respectively). This was evident in the da and pulping of the materials. Soda pulping of the iole at 14% A.A. produced considerably more yield (48.9%) bined with a lower Kappa number (24.0) than the soda ping of the midrib at the same A.A. [yield (28.7%), ppa number (105.7)]. To achieve a Kappa number of around required only 14% A.A. in the sulphate pulping of the iole whereas 18% A.A. was needed to pulp the midrib.

The tearing strength of the pith pulps of the [illegible] was comparable to the petiole while that of the bleached and unbleached sulphate pulps of the midrib were superior. [illegible] unbleached sulphate pulps had the similar tearing strength as the petiole pulps whereas the pith and bast [illegible] of the midrib were weaker. The breaking length of the [illegible] pulps were longest as compared to that of the pulps of the midrib.

[illegible] Comparison with other non-woody fibres

Studies by Clark and Bagby ([illegible]) have shown that a [illegible] plant i.e. kenaf (Hibiscus cannabinus) has potential in papermaking. The average fibre length of the [illegible] and woody fractions is 1.28 mm. The alpha-cellulose content of kenaf at [illegible]% is comparable to spruce (softwood) and maple (hardwood) while its lignin content ([illegible]%) is considerably lower than both spruce ([illegible]%) and maple ([illegible]%).

The stalks either green or field-dried could be [illegible] processed into sulphate pulps of good quality.

An A.A. of 15 - 16.5% was needed to produce bleachable grades of pulp. Strength characteristics of kenaf pulp were similar at the same freeness level to those of commercial hardwood pulps and except for resistance to tear, comparable to softwood pulps (Clark and Bagby, [illegible]).

The bleached pulps were also blended with commercial wood pulps to produce bond papers. Bond papers containing 30% kenaf, 20% hardwood and 50% softwood pulps had good burst factor, breaking length and folding endurance but a somewhat lower tear factor than those containing 67% softwood and 33% hardwood pulp in the furnish (Clark and Bagby, 1970).

The oil palm midrib contains a higher content of alpha-cellulose compared to kenaf (36%) while the pentosans content of both materials are comparable. The lignin content of the midrib at 24.5% is slightly higher than kenaf (17.5%) possibly explaining the slightly higher A.A. (18%) required for producing bleachable pulps of the midrib.

The tearing strength of the bleached sulphate pulp of the midrib is comparable to that of the bond paper to which 30% kenaf had been added. The beating length of the bond paper was rather similar to that of the midrib pulp.

(where 24 g of OD pulp are needed for a set of 12 handsheets)

Calculations related to pulping are FRIM's adaptations of those found in Pulp and Paper Science and Technology Vol. I Pulp (Libby, 1962).

(3.h) Kappa number of pulp

	1	2
Wt. of beaker (g)	42.8467	52.8722
Wt. of beaker + AD pulp (g)	48.2792	58.1705
Wt. of AD pulp (g) [A]	5.4325	5.2983
(B = OD content of pulp = 37.2574)		
W = wt. of OD pulp = B/100 x A (g)	2.0240	1.9740

Calculation of Kappa number for 1

n = normality of thiosulphate solution = 0.2N

b = vol. of thiosulphate solution consumed in the blank determination = 49.8 ml

a = vol. of thiosulphate consumed in test = 27.65 ml

p = vol. of permanganate consumed

f = factor for correction to 50% permanganate consumption (dependent on the value of p)

k = Kappa number

$$p = (b - a)n/0.1$$
$$= (49.8 - 27.65)0.2/0.1$$
$$= 44.3$$
$$k = p \times f/W$$