# CHAPTER 5

## CONCLUSION

The oil palm leaflets could be converted to pulp with exclusion of the leaf blades since the leaf blades contain an abundant amount of parenchyma cells which lead to processing problems and undesirable characteristics in pulp.

Furthermore, the alpha-cellulose content of the leaf blades is on the lower side while its lignin content is relatively high thus rendering it unfavourable for papermaking. The midrib, on the other hand, contains a slightly higher amount of alpha-cellulose (44.7) compared to softwood i.e., spruce (39.4%) and a hardwood i.e., maple (41%), the two species commonly used for the production of pulp and paper.

NSSC pulping of the midrib is feasible provided the pulps are used in combinations with other pulps. Stronger pulps can be obtained at higher chemical charges but low yields and high chemical consumptions are disadvantages.

Sulphate pulping of the midrib required an A.A. of 18% to produce pulps of average yields and strengths. The pulping characteristics of the material which had similarities to low density hardwoods in terms of morphological and chemical properties could be classified as

irly good. The brightness obtained was rather low but uld be improved by means of other multiple- stage eaching.

The sulphate pulps, although not exceptional in perties could possibly be converted into medium grade ping and packaging papers (Standards Institution of aysia), now (SIRIM). Writing and printing papers could be made provided the brightness of the bleached pulp ld be further improved. Perhaps the incorporation of ger-fibred pulps would increase the strength of the per.

The present investigation indicates that the production unbleached sulphate pulps and neutral sulphite emichemical pulps from the oil palm midrib is technically ssible provided the problem of transportation of the raw erial and the time consumed in its separation from the f blades are minimised. Additional studies need to be to optimize the protocol for developing midrib pulps dy for ultimate use.

# APPENDIX

## A1. APPARENT DENSITY

| | | |
|---|---|---|
| Weight of vessel of water | (g) | $= W_1$ |
| Weight of vessel of water + sample | (g) | $= W_2$ |
| Volume of sample | (ml) | $= W_2 - W_1$ |
| Weight of OD sample | (g) | $= W_3$ |
| Therefore apparent density | (g/ml) | $= W_3/(W_2 - W_1)$ |

## A2. FIBRE MORPHOLOGY

| | |
|---|---|
| Fibre length | = l |
| Fibre diameter | = w |
| Lumen diameter | = l |
| Cell wall thickness (w) | = (w - l)/2 |
| Coefficient of suppleness | = l/w x 100 |
| Runkel ratio | = 2w/l |
| Felting power | = l/w |

## PROXIMATE CHEMICAL ANALYSES

### (a) Moisture content

| | 1 | 2 |
|---|---|---|
| of weighing bottle (g) | 38.5778 | 24.7821 |
| of weighing bottle + AD ple (g) | 38.9517 | 25.9499 |
| of AD sample [A] (g) | 1.3739 | 1.1678 |
| of weighing bottle + OD ple (g) | 39.8435 | 25.8600 |
| of OD sample (g) | 1.2657 | 1.0779 |
| of moisture [B] (g) | 0.1082 | 0.0899 |
| moisture = B/A x 100 | 7.8754 | 7.6982 |
| x | 7.7868 | |

tor to convert to OD equivalent of original sample
= (100 - 7.7868)/100
= 0.9221

### (b) Ash content

| | 1 | 2 |
|---|---|---|
| of crucible (g) | 34.6904 | 32.3293 |
| of crucible + AD sample (g) | 37.6084 | 32.3537 |
| of AD sample [A] (g) | 2.9180 | 2.8244 |
| of crucible + ash (g) | 34.7109 | 29.5491 |
| of ash [B] (g) | 0.0205 | 0.0198 |
| ash = B/A x 100 | 0.7025 | 0.7010 |
| h x | 0.70 | |

(c) **1% alkali solubility**

| | 1 | 2 |
|---|---|---|
| Wt. of beaker (g) | 97.58 | 96.77 |
| Wt. of beaker + AD sample (g) | 99.60 | 98.70 |
| Wt. of AD sample (g) | 2.02 | 2.03 |
| Wt. of OD sample [A] (x 0.9221) (g) | 1.8624 | 1.8717 |
| Wt. of crucible (g) | 22.5845 | 24.3556 |
| Wt. of crucible + OD residue (g) | 24.0132 | 25.7977 |
| Wt. of residue [B] (g) | 1.4287 | 1.4421 |
| Wt. of alkali solubles [A-B] (g) | 0.4337 | 0.4295 |
| % of alkali solubles [(A-B)/A x 100] | 23.2872 | 22.9471 |

Mean % 23.12

(d) **Alcohol-benzene (A/B) solubility**

| | 1 | 2 |
|---|---|---|
| Wt. of fritted glass crucible (g) | 1.7424 | 1.6418 |
| Wt. of fritted glass crucible + AD sample (g) | 3.7079 | 3.2466 |
| Wt. of AD sample (g) | 1.9655 | 1.6048 |
| Wt. of OD sample [C] (x 0.922) (g) | 1.8122 | 1.4796 |
| Wt. of extraction flask (g) | 89.1383 | 94.3641 |
| Wt. of extraction flask + OD residue (g) | 89.2581 | 94.4596 |
| Wt. of OD residue [D] (g) | 0.1198 | 0.0955 |
| % of alcohol-benzene solubles [(C-D)/C x 100] | 6.6107 | 6.4544 |

Mean % 6.53

Factor to convert to OD equivalent (eq.) = (100 - 6.53)/100

= 0.9347

(c) **1% alkali solubility**

| | 1 | 2 |
|---|---|---|
| . of beaker (g) | 97.38 | 96.77 |
| . of beaker + AD sample (g) | 97.60 | 98.70 |
| . of AD sample (g) | 2.02 | 2.03 |
| . of OD sample [A] (x 0.9221) (g) | 1.8624 | 1.8717 |
| . of crucible (g) | 22.5845 | 24.3556 |
| . of crucible + OD residue (g) | 24.0132 | 25.7977 |
| . of residue [B] (g) | 1.4287 | 1.4421 |
| . of alkali solubles [A-B] (g) | 0.4337 | 0.4295 |
| of alkali solubles (-B)/A x 100] | 23.2872 | 22.9471 |
| an % | 23.12 | |

(d) **Alcohol-benzene (A/B) solubility**

| | 1 | 2 |
|---|---|---|
| . of fritted glass crucible (g) | 1.7424 | 1.6418 |
| . of fritted glass crucible + AD mple (g) | 3.7079 | 3.2466 |
| . of AD sample (g) | 1.9655 | 1.6048 |
| . of OD sample [C] (x 0.922) (g) | 1.8122 | 1.4796 |
| . of extraction flask (g) | 89.1383 | 94.3641 |
| . of extraction flask + OD idue (g) | 89.2581 | 94.4596 |
| . of OD residue [D] (g) | 0.1198 | 0.0955 |
| of alcohol-benzene solubles C x 100) | 6.6107 | 6.4544 |
| an % | 6.53 | |

tor to convert to OD equivalent (eq.) = (100 - 6.53)/100

= 0.9347

f original sample)

(c) **Moisture content of A/B sample**

| | 1 | 2 |
|---|---|---|
| of weighing bottle (g) | 23.8006 | 39.3158 |
| of weighing bottle + AD A/B mple (g) | 25.1612 | 40.5530 |
| of AD A/B sample (g) | 1.3606 | 1.2372 |
| of weighing bottle + OD A/B mple (g) | 25.0285 | 40.4316 |
| of OD A/B sample (g) | 1.2279 | 1.1158 |
| of moisture (g) | 0.1327 | 0.1214 |
| moisture | 9.7531 | 9.8125 |
| % | | 9.7828 |

tor to convert to OD eq. of original sample
= (100 - 9.7828)/100
= 0.9022

(d) **Hot water solubility**

| | 1 | 2 |
|---|---|---|
| of weighing bottle | 0.3905 | 0.3911 |
| of weighing bottle + AD A/B mple (g) | 2.1037 | 2.0262 |
| of AD A/B sample (g) | 1.7132 | 1.6351 |
| of OD A/B sample (x 0.9022) (g) | 1.5456 | 1.4752 |
| of OD eq. of original sample (C) 0.9347) | 1.6536 | 1.5782 |
| of crucible + OD extracted mple (g) | 26.2697 | 25.7862 |
| of crucible (g) | 24.7678 | 24.3518 |
| of OD extracted sample (g) | 1.5019 | 1.4344 |

| | | |
|---|---|---|
| ..t. of hot water solubles (B) (g) | 0.1519 | 0.1438 |
| . of hot water solubles (B/C x 100) | 9.1739 | 9.1136 |
| ...an % | 9.14 | |

...(g) **Lignin**

| | 1 | 2 |
|---|---|---|
| ... of beaker (g) | 31.9636 | 31.4488 |
| ... of beaker + AD A/B sample (g) | 32.9953 | 32.4549 |
| ... of AD A/B sample (g) | 1.0318 | 1.0061 |
| ... of OD A/B sample (x 0.8972) (g) | 0.9309 | 0.9077 |
| ... of OD eq. of original sample ... (/0.9347) | 0.9959 | 0.9711 |
| ... of crucible + lignin (g) | 25.6981 | 24.6405 |
| ... of crucible (g) | 25.4543 | 24.3093 |
| ... of lignin (g) | 0.2438 | 0.2372 |
| ... of lignin (B/C x 100) | 24.4804 | 24.4259 |
| ...an % | 24.45 | |

...(h) **Pentosans**

...l. of $KBrO_3$ (0.1N) = 25 ml (equivalent to 0.0025 g-atom ...mine)

...l. of KBr (10%) = 10 ml

...trant of blank = 24.70 ml

...l. of $Na_2S_2O_3$ = 13.15 ml (1st titration)

= 13.05 ml (2nd titration)

1st Titration

$m_1V_1 = m_2V_2$

$m_1 (24.70) = (0.1) (25)$

$m_1 = (0.1) (25)/24.70$
$= 0.101N$

13.15 ml of 0.101N $Na_2S_2O_3$ = 13.15 ml of 0.101N $I_2$

= 13.15 ml of 0.101N $Br_2$

= 13.15 x 0.101 g-atom bromine

= $1.32815 \times 10^{-3}$ g-atom bromine

Amount of $Br_2$ used = 0.0029 = $1.32815 \times 10^{-3}$ atoms

= $1.7185 \times 10^{-3}$

4.05 g-atom bromine = 90 g furfural

Wt. of furfural taken = $90/4.05 \times 1.17815 \times 10^{-3}$

= 0.027727

Total wt. of pentosans = 1.2 x 3 x 0.2777

= 0.14166

% of pentosans = 0.141/0.6371 x 100

= 22.24

| | 1 | |
|---|---|---|
| [illegible] of weighing bottle (g) | 0.9119 | |
| [illegible] of weighing bottle + AD A/B sample (g) | 1.5719 | |
| [illegible] of AD A/B sample (g) | 0.6600 | |
| [illegible] of OD A/B sample (x 0.9022) (g) | 0.5955 | |
| [illegible] of OD eq. of original sample (/0.9347) (g) | 0.6371 | |
| [illegible] of $Na_2S_2O_3$ (ml) | 13.15 | |
| [illegible] of pentosans | 22.2414 | |
| [illegible] an% | | 22.4 |

## (ii) Holocellulose

| | 1 | |
|---|---|---|
| [illegible] of beaker | 0.8935 | |
| [illegible] of beaker + AD A/B sample (g) | 2.3453 | |
| [illegible] of AD A/B sample (g) | 1.4518 | |
| [illegible] of AD A/B sample (x 0.9022) (g) | 1.3098 | |
| [illegible] of OD eq. of original sample (/0.9347) | 1.4013 | |
| [illegible] of crucible (g) | 17.0758 | |
| [illegible] of crucible + holocellulose (g) | 18.0374 | |
| [illegible] of holocellulose [D] (g) | 0.9616 | |
| [illegible] of holocellulose (D/C x 100) | 68.6219 | |
| Mean % | | 68.3 |

(j) **alpha-cellulose**

| | 1 | 2 |
|---|---|---|
| ... of OD A/B sample (g) | 1.3098 | 1.6098 |
| ... of OD eq. of original sample ... (/0.9347) | 1.4013 | 1.7223 |
| ... of crucible (g) | 24.5476 | 23.4470 |
| ... of crucible + OD alpha-cellulose | 25.1747 | 24.2177 |
| ... of OD alpha-cellulose (g) | 0.6271 | 0.7707 |
| ... alpha-cellulose | 44.7513 | 44.7483 |

... %  44.75

## 3. TERMS USED IN ALKALINE PULPING

In the soda process, the active chemical is sodium hydroxide whereas sodium hydroxide and sodium sulphide are the active chemicals in the sulphate process.

Active alkali - soda process = NaOH expressed as $Na_2O$

Active alkali-sulphate process = (NaOH + $Na_2S$) expressed as $Na_2O$

Sulphidity-sulphate process = the ratio of sodium sulphide to the Active Alkali; all sodium compounds expressed as sodium oxide

| | 1 | 2 |
|---|---|---|
| Wt. of weighing bottle (g) | 0.9119 | 0.9119 |
| Wt. of weighing bottle + AD A/B sample (g) | 1.5719 | 1.5654 |
| Wt. of AD A/B sample (g) | 0.6600 | 0.6535 |
| Wt. of OD A/B sample (x 0.9022) (g) | 0.5955 | 0.5896 |
| Wt. of OD eq. of original sample (/0.9347) (g) | 0.6371 | 0.6308 |
| Vol. of $Na_2S_2O_3$ (ml) | 13.15 | 13.05 |
| % of pentosans | 22.2414 | 22.6512 |
| Mean % | 22.45 | |

(iii) **Holocellulose**

| | 1 | 2 |
|---|---|---|
| Wt. of beaker | 0.8939 | 0.8929 |
| Wt. of beaker + AD A/B sample (g) | 2.3453 | 2.6772 |
| Wt. of AD A/B sample (g) | 1.4518 | 1.7843 |
| Wt. of AD A/B sample (x 0.9022) (g) | 1.3098 | 1.6098 |
| Wt. of OD eq. of original sample (/0.9347) | 1.4013 | 1.7223 |
| Wt. of crucible (g) | 17.0758 | 16.1539 |
| Wt. of crucible + holocellulose (g) | 18.0374 | 17.3272 |
| Wt. of holocellulose (D) (g) | 0.9616 | 1.1733 |
| % of holocellulose (D/C x 100) | 68.6219 | 68.1240 |
| Mean % | 68.37 | |

(c) **alpha-cellulose**

| | 1 | 2 |
|---|---|---|
| Wt. of OD A/B sample (g) | 1.5098 | 1.6098 |
| Wt. of OD eq. of original sample (/0.9347) | 1.4013 | 1.7223 |
| Wt. of crucible (g) | 24.5476 | 23.4470 |
| Wt. of crucible + OD alpha-cellulose | 25.1747 | 24.2177 |
| Wt. of OD alpha-cellulose (g) | 0.6271 | 0.7707 |
| % alpha-cellulose | 44.7513 | 44.7483 |
| Mean % | | 44.75 |

## VI. TERMS USED IN ALKALINE PULPING

In the soda process, the active chemical is sodium hydroxide whereas sodium hydroxide and sodium sulphide are the active chemicals in the sulphate process.

Active alkali - soda process = NaOH expressed as $Na_2O$

Active alkali-sulphate process = (NaOH + $Na_2S$) expressed as $Na_2O$

Sulphidity-sulphate process = the ratio of sodium sulphide to the Active Alkali; all sodium compounds expressed as sodium oxide

(a) **Preparation and titration of sodium hydroxide solution**

NaOH (450 g) was dissolved in $H_2O$ (3 L)

For titration, 25 ml of this solution was diluted to 250 ml and 25 ml aliquots were titrated with 0.5N HCl to phenolpthalein end point.

Titration to end point = 20.9 ml

$$m_1v_1 = m_2v_2$$

$$0.5 \times 20.9 = m_2 (25)$$

$$m_2 = 0.5 \times 20.9/25 = 0.418$$

Since this is a 10 fold dilution,

concentration of NaOH (as $Na_2O$) in the original solution = $0.418 \times 33 \times 10$

= 129.58 g/l

(b) **Preparation and titration of sodium sulphide solution**

Sodium sulphide (500 g) was dissolved in $H_2O$ (2 L).

For titration, 20 ml of this solution was diluted to 200 ml and 20 ml aliquots titrated with 0.5N HCl.

Titration to phenolpthalein end point = 7.1 ml

Titration to methyl orange end point = 13.1 ml

Then, the volume of 0.5N HCl equivalent to the $Na_2S$ content of 20 ml solution = 2(13.1 - 7.1) ml

= 12 ml

Then concentration of $Na_2S = 12 \times 0.5/20$

Since this is a 10 fold dilution,

concentration of $Na_2S$ (as $Na_2O$) = 12 x 0.5 x 31 x 10/20

= 93 g/l

(c) **Determination of the amount of sodium hydroxide in the sodium sulphide solution**

From the above titration figures,

Amount of NaOH present = (13.1 - 12) x 0.5

Concentration of NaOH = (13.1 - 12) x 0.5/20

Since this is a 10 fold dilution,

concentration of $Na_2S$ (as $Na_2O$)

= (13.1 - 12) x 0.5 x 31 x 10/20

= 8.525 g/l

(d) **Calculations for the pulping conditions in a soda cook**

A.A = 14%

Concentration of prepared NaOH solution = 129.58 g/l

Ratio of sample:liquor = 1:5

O.D. wt. of raw material = 400 g

Factor to convert AD to OD equivalent = 0.8672
(calculated from moisture content of material)

AD weight = 400/0.8672

= 461 g

14% NaOH = 14/100 x 461 = 64.54 g NaOH

$Na_2O$ = (23 + 23 + 16) = 62/2 = 31

NaOH = (23 + 16 + 1) = 40

Equivalent weight of NaOH = 64.54 x 31/40 = 50.02

Concentration of prepared NaOH solution = 129.58 g/l

Vol. of NaOH (129.58 g/l) = 50.02 x 1000/129.58

= 386 ml

Ratio of sample:liquor = 1:5

= 400:2000

Actual vol. of water to add = (2000 - 386 - 61) ml

= 1553 ml

(c) Calculations for the pulping conditions in a sulphate cook

A.A. = 18%

Sulphidity = 25%

$Na_2S$ = 93 g/l

NaOH in $Na_2S$ = 8.525 g/l

OD sample = 500 g

AD sample = 540 g (moisture available) = 540 - 500

= 40 g

Wt. of NaOH (as $Na_2O$) = 18(100-25/100) x 500/100

= 67.5

Wt. of $Na_2S$ required = 18 x 25/100 x 500/100

= 22.5

Vol. of $Na_2S$ required = 22.5 x 1000/93 = 241.935

= 242 ml

Wt. of NaOH in $Na_2S$ = 241.935 x 8.525/1000

= 2.06 g

Wt. of NaOH required = 67.5 - 2.06 = 65.44 g

Vol. of NaOH required = 65.44 x 1000/246.45

= 265.5 ml

Actual vol. of water to add = 2500-1242-265.5-40) ml

= 1952.5 ml

i) **Estimation of chemical consumed in a sulphate digestion**

Sulphidity of liquor = 25%

A.A. of liquor = 18%

Let titration of 5 ml of ashed liquor to pH 4.2

= 13.1 ml (1st titration)

mean = 13.2 ml

Let titration of 10 ml of liquor with carbonate removed

to pH 8.3 = 67.8 ml (1st titration)

= 67.8 ml (2nd titration)

mean = 67.8 ml

Then, total alkali in 20 ml black liquor

= 4 x 67.8 ml 0.1N HCl

= 271.2 ml

and the A.A. remaining in 20 ml of black liquor

= 2 x 13.2/1 - 25/200

= 30.17

Then, % chemical consumed = (271.2 - 30.17) x 100/271.2

= 88.8%

Chemical screened as A.A. on OD raw material

= 88.89 x 18/100

= 16%

**Screenings**

Total wt. of wet pulp = 1034 g

Wt. of OD screenings = 19 g

% of screenings on OD pulp = 19/1000 x 100 = 1.9%

Moisture content of 18% sulphate pulp

| | A | B |
|---|---|---|
| Wt. of beaker + lid (g) | 37.0127 | 39.1015 |
| Wt. of beaker + lid + wet pulp (g) | 40.0483 | 42.8409 |
| Wt. of beaker + lid + OD pulp (g) | 38.1406 | 40.4985 |
| Wt. of OD pulp (g) | 1.1279 | 1.3970 |
| Wt. of moisture (g) | 1.9077 | 2.3424 |
| % of moisture | 62.8442 | 62.6411 |
| Mean | 62.74 | |

OD content of A = 1.1279 x 100/3.0356 = 37.1558%

OD content of B = 1.3971 x 100/3.7394 = 37.3589%

Mean = 37.2574%

Then,

equivalent OD pulp = 549.7 x 35.44/100 = 194.81 g

yield = 194.81/500 x 100 = 38.96%

Wt. of moist pulp for papermaking = 24/35.44 x 100

= 67.72 g

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

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

## 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 x f/W

= 44.3 x 0.986/2.0240
= 21.5809

Mean value of k (1 and 2) = 21.4

## NSSC pulping

### Preparation and titration of sodium sulphite solution

Sodium sulphite (500 g) was dissolved in $H_2O$.

For titration, 25 ml of this solution was diluted to 250 ml. 0.2N $I_2$(30 ml) was added to 10 ml of this solution and a few drops of dilute $H_2SO_4$ were added.

This solution was then titrated with 0.2N $Na_2SO_3$ using starch as indicator.

Titration to end point = 16.60 (1st titration)
= 16.55 (2nd titration)
mean = 16.575 ml = n

Then concentration of $Na_2SO_3$
= (30 - n/10) x 63 x 0.2
= 30 - 16.575/10 x 63 x 0.2

Since this is a 10 fold dilution,

Concentration of $Na_2SO_3$
= 30 - 16.575/10 x 63 x 0.2 x 250/25
= 169.155 g/l

## A6. BLEACHING

### 1st stage: chlorination

#### a) Determination of natural chlorine demand

If the Kappa number of the pulp to be bleached is between 18 to 20, the natural chlorine demand will be about 7 to 8% on OD pulp. For kappa number between 25 to 28, 2 to 3% chlorine will be used.

In this case, the kappa number of the pulp was 21.4, therefore 5% chlorine was used on the OD pulp.

A total of 200 g OD pulp was to be bleached. 100 g OD pulp was bleached at a time, each in a plastic bag.

#### b) Preparation of chlorine water

| | A | B |
|---|---|---|
| Wt. of flask + KI (g) | 65.2441 | 64.2582 |
| Wt. of flask + KI + $Cl_2$ water (g) | 75.2080 | 74.3008 |
| Wt. of $Cl_2$ water (g) | 9.9639 | 10.0426 |
| Titre of 0.1N $Na_2S_2O_3$ (ml) | 25.10 | 25.25 |
| Concentration of $Cl_2$ water g/l | $8.9428 \times 10^{-3}$ | $8.9257 \times 10^{-3}$ |
| Mean concentration g/l | $8.9343 \times 10^{-3}$ | |

1 ml of 0.1N $Na_2S_2O_3$ = 0.00355 g $Cl_2$

Calculation for A

Amount of chlorine (g) in the $Cl_2$ water

= 0.00365 x 25.1

5 g $Cl_2$ is contained in 9.9639 x 5/0.0891

= 559.14 ml

Mean volume (from A and B) = 560 ml

Volume of chlorine water containing 5 g $Cl_2$ = 560 ml

= 560 g

General conditions:

Stock consistency = 3%

Temperature = $20^{o}C$

Time = 1 hr

A total of 200 g OD pulp was to be bleached.

100 g OD pulp was bleached at a time, each in a plastic bag.

P = OD pulp = 100 g

AD pulp = 268.40 g

W = water

$P/P + W + Cl_2H_2O \times 100 = 3$

Let $y = P + W + Cl_2H_2O$

$100/y \times 100 = 3$

$y = 100(100)/3$

$P + W + Cl_2H_2O = 3333$ g

100 + W + 560 = 3333 g

W = 3333 - 100 - 560 = 2673 g

560 g of $Cl_2H_2O$ and 2673 g of $H_2O$ were added to the pulp to make up to 3333 g.

## 2nd stage: alkali extraction

General conditions:

Stock consistency = 5%

Temperature = 60°C

Time = 1 hr

Concentration of NaOH on OD pulp = 3%

P = pulp

W = water

Let y = P + W + NaOH soln.

P/P + W + NaOH soln. x 100 = 5

100/y x 100 = 5

y = 100(100)/5

= 2000 g

P + W + NaOH soln. = 2000 g

Water was added to bring the total weight to 2000 g.

## 3rd stage: hypochlorite bleaching

All the pulp from stage two was weighed and three portions, each equal to 1/10 of the total weight was taken (assuming no loss of yield on bleaching). Three trials containing 1,

and 2% available chlorine on OD unbleached pulp was undertaken.

General conditions:

Stock consistency = 6%

Temperature = 30°C

Time = 2 hr

**Preparation of bleaching solution**

| | 1 | 2 |
|---|---|---|
| Wt. of flask + KI (g) | 65.2758 | 43.1456 |
| Wt. of flask + KI + bleaching soln. (g) | 75.6115 | 53.4557 |
| Wt. of bleaching soln. (g) | 10.3357 | 10.3101 |
| Titre of 0.1N $Na_2S_2O_3$ | 72 | 72 |
| Concentration of $Cl_2$ in bleach soln. | 0.02473 | 0.02479 |
| Mean concentration g/l | 0.02476 | |

(Calculations as in 1st stage)

(Below is an example of the calculation for one bleaching trial):

Concentration of $Cl_2$ on OD pulp (%) 1

Wt. of $Cl_2$ (g) 1/100 x 10

= 0.1

Wt. of bleaching soln. required 0.1/0.2476

= 4.0387

x 10 dilution = 40.39

| | |
|---|---|
| 6% stock consistency (g) | 167 |
| $H_2O$ required (g) | 116.61 |

After two hours reaction time,

| | |
|---|---|
| Wt. of flask + KI (g) | 101.2 |
| Wt. of flask + liquor (g) | 222.46 |
| Wt. of liquor ($P_3$) | 121.26 |
| Titre of 0.1N $Na_2S_2O_3$ (r) | 1.80 |
| Concentration of available $Cl_2$ remaining (5.9285 x $r/P_3$) | 0.09 |

Graph of quantity of chlorine remaining (residual chlorine) against the percentage of chlorine added on dry pulp was plotted.

For the large scale bleaching, that quantity of chlorine where the residual chlorine was 0.2% was used.

## Large scale bleaching

| | 1st Bag | 2nd Bag |
|---|---|---|
| Residual $Cl_2$ on OD pulp (%) | 0.3 | 0.2 |
| Concentration of $Cl_2$ on OD pulp (%) | 1.3 | 1.3 |
| Wt. of chlorine required (g) | 1.3/100 x 70 = 0.91 | 1.3/100 x 100 = 1.3 |
| Wt. of bleaching soln. required (g) | 0.91/0.02476 = 36.75 | 1.3/0.2476 = 52.50 |
| x 10 dilution (g) | 367.5 | 525.0 |
| Wt. stock consistency [total wt. required] (g) | 1167 | 1167 |
| $H_2O$ required (g) | 729.5 | 1042 |

## Yield of bleached pulp

Total wt. of AD bleached pulp = 725.6 g

## Moisture content of bleached pulp

| | A | B |
|---|---|---|
| Wt. of beaker + cover (g) | 29.5742 | 28.6583 |
| Wt. of beaker + cover + AD pulp (g) | 36.3335 | 36.3457 |
| Wt. of AD pulp (g) | 6.7593 | 7.6874 |
| Wt. of beaker + cover + OD pulp (g) | 31.0345 | 30.3075 |
| Wt. of OD pulp (g) | 1.4603 | 1.6492 |
| Wt. of moisture (g) | 5.2990 | 6.0382 |
| % moisture | 78.3957 | 78.5467 |
| Mean % | 78.47 | |

OD content of A = 1.4603/6.7593 x 100 = 21.6043

OD content of B = 1.4603/6.7593 x 100 = 21.4533

Mean OD content = 21.5288

Equivalent OD pulp = 21.5288/100 x 725.6 = 156.2130

Yield of bleached pulp = 156.2130/170 x 100 = 91.89%

Loss of yield on OD unbleached pulp = 100 - 92 = 8%

## HANDSHEET FORMATION

Under ideal conditions and without variations, the OD equivalent of each handsheet should be 1.15 g (an equivalent 60 g.s.m.). However, in practice, 1.20 g per sheet is allowed in order to take non-consistencies due to level control in stock delivery. If the weights of the trial sheets were not close to 0.05 g, then a third specimen was withdrawn to confirm the trial. The stock concentration was corrected as shown in the example below.

Let wt. of trial sheet (g) = w = 1.22

Vol. of water left in the stock

= 14 litres - vol. of trial sheets.

Assuming 2 litres were taken for trial sheets.

Vol. of water left in the stock = 12 litres

Wt. allowed per sheet (g) = W = 1.20

Vol. of water to add

= [(1.22/1.20 x 12,000) - 12,000] ml

= 200 ml

If the trial sheet weighs less than the wt. allowed per sheet,

Vol. of water to remove = 12,000 - (w/W x 12,000) ml.

## PHYSICAL TESTS OF HANDSHEETS

A8(a) **Basis weight**

Basis weight = BW = (321 x m/n)g/$m^2$

m = OD mass of test pieces in g

n = number of test pieces

Let m = 2.899

n = 16

BW = 321 x 2.899/16

= 58.16 = 58.2 g/$m^2$

*(This value is to be used in the subsequent calculations)*

A8(b) **Tear index**

Tear index = (9.8066 x reading x 2/BW) mN.$m^2$/g

where 9.8066 = full loading acting on one sheet in milli Newton (mN)

Let mean reading = 52.25

Tear index for a single sheet

= 9.8066 x 52.025 x 2/58.16

= 17.61 mN.$m^2$/g

A8(c) **Bursting strength**

Burst index = (98.066 x reading/BW) $kPa.m^2/g$

BW = $g/m^2$

Set reading = 2.3 $kg.f/cm^2$

Burst index = 98.066 x 2.3/58.16

= 3.88 = 3.9 $kPa.m^2/g$

A8(d) **Tensile strength**

Tensile index = (66.667 x load/BW) N.m/g

load = Newton

BW = $g/m^2$

Set mean load = 45.1N

Tensile index = 66.667 x 45.1/58.16

= 51.70 = 51.7 N.m/g

A8(e) **Breaking length**

Breaking length = Tensile index/9.8066 km

Breaking length = 51.7/9.8066

= 5.27 km

A8(f) **Tensile energy absorption (TEA)**

TEA = (TE/1.5 x 100) $J/m^2$

TE = tensile energy

TEA = 1.085/1.5 x 100 = 72.33 $J/m^2$

A8(g) **TEA index**

TEA index = (TEA/BW x $10^3$) J/g

= 72.33/58.16 x $10^{-3}$ m3/g

= 1243.6

= 1244 J/g

A11(b) **Stretch**

Stretch = (El/90 x 100)%

El = mm

Mean El = 4.37/90 x 100

= 4.855

= 4.9%