Paper 083

Sisal Waste Ctmp Pulping for Use In Fibre-Cement Composites

Savastano Junior, H. (a)[1];Joaquim, A.P. (a); Warden, P.G. (b); Coutts, R.S.P. (c)
(a) University of São Paulo – FZEA- P.O. Box 23 CEP 13635-900
Pirassununga SP – Brazil
(b) CSIRO Forestry and Forest Products, Private Bag 10,
Clayton South VIC 3169, Australia
(c) ASSEDO Pty Ltd, 75 Sandringham Road, Sandringham, Vic. 3191, Australia
Corresponding author. Fax 55 19 3565 4114 *e-mail:* holmersj@usp.br

***Abstract*:** *Brazilian sisal waste fibres were separated from non-fibrous material and submitted to a low temperature chemi-thermomechanical pulping (CTMP) process, with a view to their use as reinforcement in cement products. Thermomechanical (TMP) and chemi-thermomechanical pulps of commercial sisal strands were also prepared to determine appropriate processing parameters and to provide a comparison with the alternative pulp. After a Sommervile mesh screening and washing, sisal by-product CTMP possessed Canadian standard freeness values between 460 and 500, compatible with those used with the slurry vacuum de-watering production method. The pulps contained fibrillated filaments, less than 5% fines, and fibre aspect ratios greater than 160. Sisal by-product pulp showed evidence of flexible fibres, giving rise to an expectation of improved bonding between phases in cement composites.*

Keywords: *sisal, waste, CTMP, cementicious composites.*

Introduction

The cost of chemically pulped fibre and its further preparation by refining typically represents a significant proportion of the overall cost of producing cellulose fibre-cement sheet by the Hatschek process. An opportunity exists in the identification of cheaper fibre resources and preparation methods yielding acceptable processing characteristics to improve the viability of fibre-cements in low-cost building applications.

Regardless of relatively high-energy consumptions, mechanical pulping processes have a range of advantages over chemical processes. As indicated by Coutts [1], effluent treatment and disposal are less troublesome, chemical requirements are lower, production costs are lower (around half the price of kraft pulp) and mills are economically viable at a smaller scale.

As a contribution toward the production of viable fibre-cement materials in developing tropical countries, this work investigated the use of waste sisal fibre and mechanical pulping procedures.

Experimental

Sisal fibres (*Agave sisalana*) from Brazilian agricultural wastes currently without commercial value were provided by the "Associação de Pequenos Produtores do Município de Valente (Apaeb)", Bahia, Brazil. Good quality, mechanically combed Tanzanian sisal fibre provided by Geo. Kinnear & Sons P/L, Melbourne, Australia, was used for comparison with the waste fibres and preliminary adjustment of mechanical pulping procedures applied to non-wood materials.

Strand fibres of approximately 30-mm length were submitted to low temperature thermomechanical pulping (TMP) or chemi-thermomechanical pulping (CTMP) in a laboratory Asplund defibrator, based on related literature [3]. The pulps produced were then refined in a laboratory Bauer refiner, using 8 passes in the case of TMP, 6 in the case of commercial CTMP and 3 for the by-product CTMP. The refined pulps were then passed through a 0.229 mm slotted Packer screen to remove shives, vacuum de-watered, pressed, crumbed and stored in sealed plastic bags under refrigeration. Prior to de-watering, the CTMP from waste fibre was subjected to a supplementary Somerville screening (0.180-mm mesh) to reduce its fines content, then washed. Samples were gold coated and analysed in a Philips XL30 field emission gun (FEM) scanning electron microscope (SEM) using a secondary electron (SE) detector at acceleration voltages from 2.0 to 5.0 kV.

Results and Discussions

Chemical compositions from the literature [2] indicate that sisal fibres are, in comparison to softwood fibres: similar in ash (0.6-1.1% for sisal *versus* <1% for softwood) and cellulose (43-56% *versus* 40-45%), higher in hemi-cellulose (pentosans) (21-24% *versus* 40-45%) and lower in lignin content (7.6-9.2% *versus* 26-34%). From this general information one could suppose non-wood fibres may be suitable for cheap pulping [2], especially by mechanical based processes.

Characterization of the pulps yielded the data shown in Table 1. Kappa numbers over 50 are indicative of high lignin contents and a lack of suitability for submission to bleaching operations related to papermaking processes (Appita P201 m-86).

Table 1. Pulp and fibre properties

Fibre	*Commercial sisal CTMP*	*Commercial sisal TMP*	*By-product sisal CTMP*
Screened yield (%)	73.2	58.5	43.4
Kappa number (1)	80.4	55.2	50.5
Freeness (ml) (2)	224	5	500
Length-weighted average length (mm)	2.25 (3)	2.46 (3)	1.53 (4)
Fines (%) (5)	2.34	3.88	2.14
Coarseness (mg.m^{-1})	N/A	N/A	0.138
Fibre width (μm) (6)	10.2	12.7	9.4
Aspect ratio	221	194	163

(1) Appita P201 m-86; (2) AS 1301.206s-88; (3) Galai WCIS-100 (2nd moment of inertia >1); (4) Kajaani FS-200; (5) Arithmetic basis; (6) Average of 20 determinations by SEM; N/A – not available data

The Somerville mesh screening had a positive effect on the reduction of fines (particles under 0.200-mm) in the by-product sisal CTMP. The main advantage provided by the screening was the freeness adjustment, since values less than 300 ml can be a problem for fibre-cement production based on the Hatschek process [4], especially during the vacuum de-watering stage.

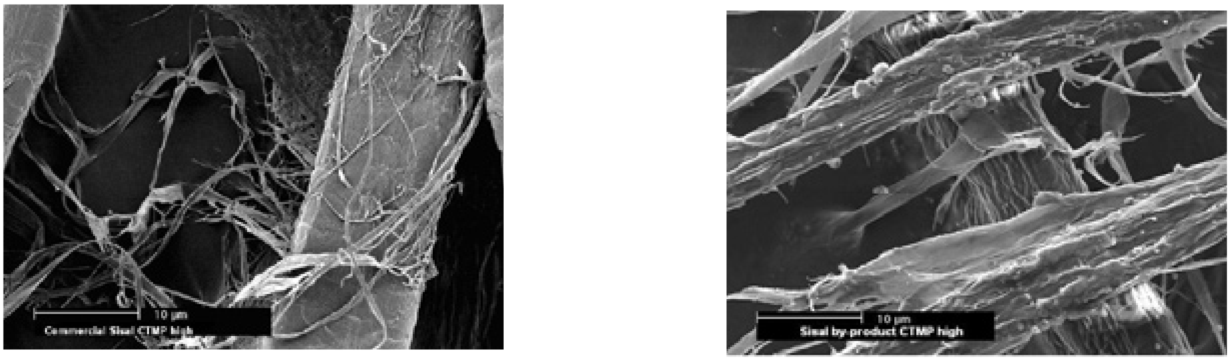
The average fibre lengths in the pulps were considered high, resulting in stronger anchorage in the matrix [5]. As a consequence, the cement composites show an improvement in tensile strength; however this is accompanied by a decrease in energy absorption due to the predominance of fibre fracture. Aspect ratio (l/d) values over 160 are further cause for fibre fracture during mechanical stressing of cement-based composites. An analogous study by Coutts [6], carried out on strand sisal in OPC, found the ideal aspect ratio of strands to be in the 110 ± 50 range for a desirable co-existence of fibre fracture and fibre pullout.

The CTMP from the waste raw material had a length-weighted average fibre length of 1.53 mm and a low incidence of filaments longer than 2.5 mm. The pulps from commercial sisal had a comparatively high incidence of longer particles, indicating less efficient fibre separation. These coarse pulps were unsuited to analysis using the Kajaani instrument due to the risk of capillary blockage and were instead characterised using a Galai particle size analyser. The coarseness of the waste pulp was comparable to values typical of softwood and hardwood pulps (e.g. *Pinus radiata*, 0.184 mg.m^{-1}; *Eucalyptus grandis*, 0.107 mg.m^{-1}), denoting thin walled filaments likely to provide an acceptable spatial fibre network configuration [5].

The commercial strand fibres required a relatively high energy input during Bauer refining operations, denoting some deficiency in the Asplund thermomechanical defibration. In addition, the screened yields of these pulps were higher than that of the pulp from waste material.

Only three passes through the Bauer refiner were required to impart an acceptable degree of conformability and fibrillation to the by-product CTMP. The reduction in energy consumption was the most attractive aspect for low-cost pulp production, since the price of strand wastes was found to be negligible. On the other hand, the screened yield (43%) of the sisal by-product mechanical pulp was lower than was expected [1], especially considering the low lignin content of this non-wood fibre. Reported yields could be explained by three peculiarities. Firstly, the high moisture content initially present in the raw material caused fast decomposition of the fibrous waste, forming weak fibres that were more sensitive to pulping procedures. Secondly, as the residual strand fibres were initially cleaned only by crude processes, they appeared rich in pithy material and parenchyma cells which were mostly removed during the pulping process. Finally, the Somerville mesh screening was effective in the reduction of the amount of fines since the mechanical refining caused intense damage to the fibres [5].

Comparison between micrographs of commercial and by-product sisal CTMPs (Figure 1) makes clear their different physical attributes. Residual fibres provided more refined filaments after mechanical treatment and also presented surface incrustations of non-fibrous particles.



(a) (b)

Figure 1: (a) Commercial sisal CTMP; (b) Sisal by-product CTMP.

Conclusions

Sisal by-product material was suitable for CTMP production when followed by a screening step to lower the fines content. Low screened yields could be associated with the residual origin of the raw material and the removal during the pulping process of a high amount of non-fibrous material. Improved collection and storage of the raw material, and cleaning to reduce its pithy component, are expected to produce higher yields in future trials. Moderate energy costs could be anticipated since a low defibration temperature and only three passes through a Bauer refiner were required to impart a high degree of fibrillation and conformability to the pulp. Fibre separation and fibrillation were less readily achieved in the TMP and CTMP pulps produced from commercial sisal strands and required significantly greater refining energy input. However, the increased energy requirements were offset to some extent by higher pulp yields.

This work has demonstrated that fibre produced cheaply by chemi-thermomechanical pulping of sisal waste meets several of the prerequisites for use in fibre-cement sheet production by Hatschek related processes, and that it may represent a feasible alternative for the production of lower-cost building materials in developing countries.

Acknowledgements

To Ms. A. Pereira and Mr. G. Langfors for their skilful assistance in the pulping procedures. To Mr. J.V. Ward and Mr M. Greaves, from Ian Wark Laboratories – CSIRO, by provision of microscopy facilities. To Fapesp, CNPq, Finep – Habitare Program and Capes - Procad Program for the financial support.

(Footnotes)

References

1. Coutts, R.S.P. High yield wood pulps as reinforcement for cement products. *Appita*, **39** (1) (Jan. 1986) 31-5.
2. Judt, M. Non-wood plant fibres, will there be a come-back in paper-making? *Industrial Crops and Products*, **2** (1993) 51-7.
3. Ramos, J.; Davalos, F. and Navarro, F. High yield pulping from sugar cane bagasse and other non wood plant fibers, an state of the art review. In *Proc. Nanjing International Symposium on High Yield Pulping,* Nov. 1997. Nanjing, Chinese Academy of Forestry, p.152-86.
4. Coutts, R.S.P. and Ridikas, V. Refined wood fibre-cement products. *Appita*, **35** (5) (March 1982) 395-400.
5. McKenzie, A.W. *A guide to pulp evaluation*. CSIRO, Melbourne (1994).
6. Coutts, R.S.P. Wood fibre reinforced cement composites. In *Natural Fibre Reinforced Cement and Concrete*, ed. R. N. Swamy, Blackie, Glasgow, 1988, pp.1-62.
7. Misra, D.K. Pulping and bleaching of nonwood fibers. In *Pulp and paper: chemistry and chemical technology*, ed. J.P. Casey, J.P. (3rd ed.), Wiley, New York, 1983, v.1, pp.504-30.