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VALORISATION OF DIFFERENT AGRICULTURAL CROPS IN PAPERMAKING APPLICATIONS

SÉVERINE SCHOTT[1], DIDIER CHAUSSY[1], EVELYNE MAURET[1], ISABELLE DESLOGES[1], ANTUNES ANABELA[2], NEREIDA CORDEIRO[3], MOHAMED NACEUR BELGACEM[1]

[1]*Laboratoire de Génie des Procédés Papetiers (LGP2) Institut National Polytechnique de Grenoble Ecole Française de Papeterie et des Industries Graphiques, BP: 65, 38402 Saint Martin d'Hčres, France*

[2]*University of Beira Interior, Department of Science and Technology of Paper, P-6200 Covilha, Portugal*

[3]*Department of chemistry, University of Madeira, 9000-390 Funchal, Portugal*

ABSTRACT

Wood fibres are presently the most widely used in the world pulp and paper industry. Yet, the use of non-wood fibres still initiates research in many countries. In Europe, the development of non-food applications for agriculture, in particular for agricultural residues, leads non-wood fibres to be reconsidered as raw material for the papermaking industry. This paper deals with the use of different agricultural crops as a source of lignocellulose fibres in order to produce papers for corrugated boards. Thus, pulps from wheat straw, *cynara cardunculus* L. and banana crops were obtained and tested as a raw material for papermaking.

INTRODUCTION

Annual plants and agricultural crops could play a determinant role in the area of pulps and papermaking. In fact, they present a good alternative for compensating the lack of woody fibres, since they give fibres with different morphologies which increase the possibilities of obtaining paper with specific properties.

Straw pulps are well known to exhibit excellent tensile strength properties, similar to hardwood pulps, but are deficient in tear strength (1). As straw pulps are usually short fibre pulp, they can be readily used for the production of writing and printing papers. In fact, the fibres will form very uniform sheets, give good printability and smoothness and in some cases improve opacity (2, 3). In this case, bleachable straw pulp grades will be used, mostly chemical pulps. Moreover, as straw pulps contain high amonts of hemicellulose, they confer good compressive strength through enhanced bonded (1, 2). They are then ideally suited for the production of corrugating medium. As this application does not need bleachable grades, high yield pulps (superior to 50 %) will be preferred.

As regards physical structure and chemical composition of straw, there are five botanical parts in straw: internodes, nodes, leaves, ears and rachis. Their proportions in weight are as follows: 54.1 % internodes, 16.9 % leaves, 14.4 % ears, 10.7 % rachis and 4.2 % nodes (4). The bast cells, which exist predominantly in the internodes, are the principal source of fibre for pulping. They are associated with epidermal cells, platelets, serrated cells and spirals, which are very small and have no fibrous characteristics. Rydohlm (5) reports that wheat straw contains 50 % bast and sclerenchyma fibres, 30 % parenchyma, 15 % epidermal cells and 5 % vessels. These components vary considerably in terms of their length, diameter, cell wall thickness and degree of lignification (6). Straw fibres are much more heterogeneous than wood fibres. The fibre dimensions of wheat straw are 680–3120 μm in length, with an average of 1450 μm, and 7–24 μm in diameter, with an average of 13 μm (7, 8). Cereal straws are very similar to hardwood fibres in terms of their length, but their diameter is smaller, which leads to a higher fibre length to diameter ratio (110:1). This ratio is close to the one of softwood fibres.

The fibre lengths of some banana pseudostems variety are about the same as for softwood (9). The fibre width, however, is intermediate between those of softwoods and hardwoods used in commercial wood pulps. These characteristics suggest that these fibres could be suitable for the pulp and paper making. The chemical composition of banana fibres showed relatively higher extractive and ash amount but lower lignin and holocellulose contents than hardwood and softwood species. This explains the relatively low pulp yield, after chemical pulping and also the low chemical requirements for pulping (9).

As regards *Cynara cardunculus* L., there were not studies displaying general characteristics of the raw material because this vegetable specie is presently growing at experimental plantation. It has been already collected and studied two subsequent years. The investigation of both collected materials will be reported here.

EXPERIMENTAL PART

Material:

Banana plants *Musa accuminata* Colla, grown in Madeira Island (Portugal), is the most wide spread species occupying almost 77 % of cultivated area and is the major economic source of the Island (1/3 of the total exportations and 20 % of the income). This activity produces a big quantity of agricultural residues which are left on the soil in order to biodegrade. For this study, the pseudo-stems of *Musa acuminata* Colla were harvested from a banana plantation in Funchal. The pseudo-stems of mature plants (after cutting the bananas bunch), randomly selected, were handily separated from foliage and several sheets of the trunk were disconnected. Afterwards, they were air dried for two weeks. The dried material was then submitted to several cooking processes and conditions and different cellulosic pulps were produced. It is interesting to note that the yield of chemical pulps reached about 40 % and that the delignification time was very short, i.e. less than 15 minutes for soda-anthraquinone and/or kraft cooking processes at about 120 °C. Nevertheless, ash content can reach 15 % in banana pulp (10).

Cynara cardunculus L. (cardoon) crops were studied in terms of chemical composition and soda-anthraquinone cooking optimisation (11, 12). The results showed that the polysaccharide content is enough high to justify the cooking of cardoon despite the relatively high amount of water soluble extractives for *Cynara cardunculus* L. (ca. 10 %). For *Cynara cardunculus* L., the optimal cooking conditions, i.e. time, temperature, active alkali and anthraquinone concentration, were established. It was shown that a very short time of cooking (30 minutes after reaching an isotherm of 160 °C) gave pulps with good yield (36 %) and very acceptable kappa number of 17.

In the case of wheat straw, this study has been initiated by the French Ministry of Agriculture, Food and Rural Affairs and has been carried out in collaboration with EMC2, who developed and patented a steam explosion pulping process. This process consists in a chemical impregnation of the straw at low temperature (ambient to 60 °C), followed by a short treatment with saturated steam and a brutal decompression (13). For this study, a pilot plant equipped with a pulping reactor of 3.5 m^3 was used with the following experimental conditions (chemicals: 5 % NaOH, pressure: 19 bars, cooking temperature: 210 °C, cooking time: 7 min.) The pulp yield was about 80 % (14, 15). Finally, the straw pulp was defibering, washing and wet-pressing, these treatments leading to a decrease in the yield that reaches 60 to 70 %. In order to enhance the ability of the steam exploded straw pulp to papermaking application, the pulp was beaten in a Valley beater. As it contained a lot of impurities, it was treated by vibrating screen with 0,15 mm slots.

Fibre's Morphology Characterisation:

Concerning banana plants and Cynara cardunculus L., fibre lengths and widths were determined by optical microscopy. Finally, two fibre analyser equipments (IFA[10] and Morfi a prototype developed by Techpap France), both based on image analysis, were used to determine the fibre length and the coarseness of the studied pulps. As regards steam exploded straw pulp, the Bauer-McNett method was carried out.

Paper Properties:

Conventional hand sheet papers were made from unbeaten and beaten pulps. The basis weights of the hand sheets prepared were 130 g/m^2. The papers obtained were characterised in terms of physical, mechanical using standard methods.

RESULTS AND DISCUSSION

1. Wheat straw pulp

The characterisation of the steam exploded wheat straw pulp showed a high hemicellulose (23 %) and fine particles (60 % below 0,68 mm) contents. As a consequence, even before beating, the pulp presents a low drainability (around 35 °SR) and a high hydration degree (WRV around 2 g/g). It has also been shown that the beating of the pulp allowed developing the straw fibre's potential. It enhances the strength properties especially the SCT, CMT and Scott Bond values (table 1). These properties increase respectively from 33 to 38 kN.m/kg, 220 to

Tab. 1. *Comparative strength properties of semi-chemical straw pulp, recycled fibre pulp and EMC2 steam exploded pulp at various freenesses.*

	SCS P	Recycled fibre		EMC2 straw pulp	
Freeness (°SR)	56	46	60	47	58
Drainage time (s)	25	10	12	20	30
WRV (g/g)	2.3	1.15	1.3	2.1	2.25
Bulk (cm^3/g)	1.7	1.6	1.5	1.4	1.3
Burst Index ($kPa.m^2/g$)	3.1	2.8	3.3	2.9	3.5
Tear Index ($mN.m^2/g$)	3.5	9.4	10	4.3	3.7
Breaking length (km)	6.3	4.5	5.2	5.5	6.6
Elastic modulus (GPa)	3.2	2.7	3.1	3.5	4.3
SCT Index (kN.m/kg)	37	22	3.1	33	38
CMT_{30} (N)	230	180	24	220	225
Internal bonding strength (J/m^2)	n.d.	210	200 250	680	1020

225 N and 680 to 1020 J/m^2 for the refining degrees of 47 and 58 °SR.

As regards the highest beating level (58 °SR), the steam exploded straw pulp reached the properties of semi-chemical straw pulp. These characteristics were essential and very interesting for the production of wrapping papers.

Moreover, the screening of the pulp after beating was crucial burst index, breaking length and internal bonding strength increased respectively by 20–30 %, 10–20 % and 7–17 % according to the beating level.

Our investigation was also orientated towards mixtures of wheat straw and recycled fibres pulps. The beating, wet-pressing and drying processes have been studied, with blends containing 0, 10, 30, 50 and 100 % wheat straw pulp. In order to compare the results obtained in the beating trials, the specific refining energy was considered. An energy of 37,5 kW.h/t was found to be enough to improve the strength properties of 100 % straw paper, with a freeness not to high (near 60 °SR). This value is the one we considered for our blending method comparison. As it can be seen in the table 2, the freeness is nearly the same (63 to 67 °SR) when suspension contains straw pulp whatever the content is (between 10 and 100 %). This value is lower for a 100 % recycled fibre pulp (55 °SR). At the same straw pulp content, the mechanical properties are almost equal excepted for the specific properties studied as internal bonding strength and CMT. Compared to a 100 % recycled fibre pulp, these properties were increased when the straw content reached 30 % and 50 %. Moreover, these increases were higher when the pulps were beaten separately. However, further experiments as reported elsewhere (16) showed that the wet-pressing efficiency was reduced when the straw pulp was added, which further lead to a slower drying of the sheet.

Several industrial trials have been conducted in the field of corrugating and winding papers. Around 100 tons of paper were produced, without any problem. The board characteristics have been improved, but the productivity has been reduced (lower machine speed and higher vapour consumption).

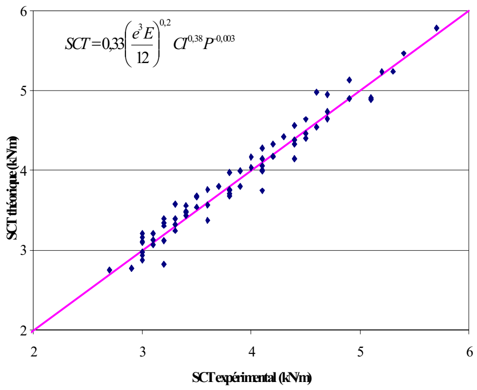

Fig. 1. *correlation between SCT experimental values and calculated values*

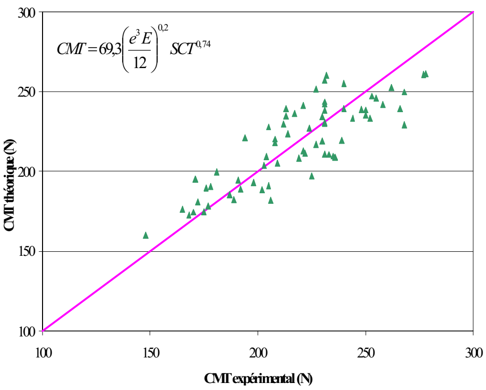

Fig. 2. *correlation between CMT experimental values and calculated values.*

with e, the thickness of the sheet (µm),
E, the Young modulus (GPa),
CI, the internal bonding strength(J/m^2),
P, air permeability (ml/min).

Tab. 2. *Mixed versus separate refining at same energy input.*

	100% steam exploded straw pulp	30/70 mixture obtained by separate refining	30/70 mixture obtained by mixed refining	50/50 mixture by separate separate refining	50/50 mixture obtained by mixed refining	100 % waste paper
Specific refining energy for straw pulp within the blend (kW.h/t)	37,5	112	11,2	75	18,8	0
Specific refining energy for waste paper within the blend (kW.h/t)	0	0	26,3	0	18,7	37,5
Specific refining energy input to the blend (kW.h/t)	37,5	33,6	37,5	37,5	37,5	37,5
Freeness (°SR)	63	67	63	65	67	55
Drainage time (s)	63	35	15	30	23	9
WRV (g/g)	2,20	1,50	1,45	1,75	1,70	1,25
Bulk (cm^3/g)	1,3	1,5	1,5	1,4	1,4	1,5
Burst index ($Kpa.m^2/g$)	3,2	3,0	3,1	3,1	3,1	2,9
Tear index ($mN.m^2/g$)	4,0	9,0	8,7	7,5	8,2	10,6
Deformation (%)	2,5	2,5	2,3	2,7	2,6	2,6
Breaking length (km)	5,7	4,7	4,7	5,0	5,2	4,7
Elastic modulus (GPa)	3,8	3,0	3,1	3,1	3,3	2,9
Bending stiffness (mN.m)	2,1	2,5	2,5	2,3	2,2	2,9
Air permeability (ml/min)	20	70	110	45	50	320
SCT index (kN.m/kg)	33	24	24	28	26	22
Internal bonding strength (j/m^2)	670	360	320	515	360	200
CMT (N)	290	245	215	295	225	195

Nevertheless, the products can be economically viable by choosing the proper furnish composition, the appropriate retention and dewatering aids and when optimising beating and wet-pressing.

The compressive strength of paper (SCT and CMT) played an important role for the determination of paperboards efficiency, especially for corrugated board and core boards. These properties could be correlated with paper properties as thickness, young modulus, internal bonding strength and air permeability. Practical models for the calculation of SCT and CMT values have been achieved (see figures 1 and 2). The relative difference between experimental and calculated values varied between 3 and 8 %.

Pulps from Cynara cardunculus L.

For *Cynara Cardunculus* pulps, the majority of fibres, i.e., 90% have an average length less than 1 mm and only 10% of the pulp fibres exceeded one millimetre. Thus, these fibres could be definitely considered as constituted in majority by short fibres. The width of fibres was also determined by optical microscopy and found about 12 and 10 mm. It is worth noting that the length measured using optical microscope was found to be very close to that measured by IFA and morfi.

In view of using these pulps in corrugated board application, a set of paper samples with a basis weight of 140 g/m^2 was prepared and characterised, as presented in Table 3 which, in addition to these data, summarises some values collected from the literature (17) and concerning other raw materials used in this field. The main conclusion which can be drawn from this set of experiment deals with the fact that although pulps prepared from our raw material (*Cynara cardunculus*) displayed a lower Shopper Riegler degree, they gave paper with high mechanical properties. This is due to the higher density of paper sheets and consequently their high fibre bonding ability. It is worth noting that these pulps were used as such and were not submitted to any beating treatment.

Tab. 3. *Comparison of mechanical properties of unbleached pulps usually used in the manufacture of fluting medium papers*

	data taken from literature					
	FP	CC	RF	NSSC	WS	SB
Schopper Riegler şSR	31	44	35	50	-	24
Basis weight (g/m²)	-	-	-	-	130	142
Bulk (cm³/g)	1.8	1.7	2.0	1.5	1.5	1.3
Density (g/cm³)	0.56	0.59	0.5	0.67	0.67	0.77
Burst index (kPa.m²/g)	2.6	2.3	2.4	2.2	1.6	3.7
Tear index(mN.m²/g)	7.9	4.9	3.2	3.4	3.5	3.3
Elongation at break %	-	-	-	-	2.2	3.2
Breaking length (km)	3.7	4.9	3.4	5.7	3.1	6.1
Zero-Span tensile (Km)	-	-	-	-	8	9.2
RCT (N)	122	-	-	-	126	180
CMT (N)	145	200	195	203	140	252

FP: Fluting Commercial papers
CC: Cynara cardunculus pulps
RF: Recycled fibres
NSSC: Hardwood NSSC pulp
WS: Wheat straw pulps
SB: Sorghum Bivis pulp

This surprising result was further studied in order to establish the origin of this phenomenon (11). In fact, the fibre flexibility was carried out and showed that the relative bonded area (RBA) as measured by ciberflex, was found relatively high, i.e., around 50 %. This value is very high when compared with common pulps with a beating degree of 24 °SR.

Moreover, the tests which were made in view of application in the area of corrugated boards, i.e., Ring Crush Test (CRT) and Concora Medium Test (CMT) gave also higher values to compare with those corresponding to the commercial fluting paper.

Tab. 4. *Properties of unbleached soda pulps from banana crops*

physical or mechanical parameter	banana crops pulps
°SR	59
basis Weight (g/m²)	136
thickness (mm)	146
specific Volume (cm³/g)	1.06
tear Index (mN.m²/g)	13.8
burst Index (kPa.m²/g)	4.7
breaking Length (Km)	6.2
elongation, %	1.44
RCT (N)	220
CMT (N)	300
FCT (kN/m²)	150

Pulps from Banana's crops

As in the case of wheat straw pulp, the pulps obtained from banana crops were found to contain a high amount of fines. Thus, about 60 % of the fibres lengthen lower than 0.5 mm. The average fibre length of the *Musa accuminata* Colla was found much lower than that of other musa species reported in the literature (9).

Hand sheet papers with a basis weight of 140 g/m¸ were made and used for the preparation of corrugating. The properties of these papers and corrugated samples are summarised in Table 4. From these data (Table 3 and 4) one can conclude that the properties of these papers made from banana crops are, at least, as good as those of commercial samples. The high Schopper degree of the non refined pulps (59 °SR) witnesses that the size of fibres is short and that high amount of fines is present in the pulps, this statement is confirmed by low specific volume. Moreover, the properties of corrugated samples are higher than those made from commercials papers (CMT value of 300 N for banana pulp against 140 N for Fluting Commercial papers)

CONCLUSION

Laboratory experiments showed that alternative fibre sources such as non-wood fibres could become more and more prevalent and desirable.

As regards straw pulp, it is possible to improve the quality of paper made out of recovered fibres by introducing 30% of steam exploded wheat straw pulp refined separately. These experiments also showed some limitations (less efficient wet-pressing, longer drying). Industrials trials were conducted without any operating problem. Paperboard of higher quality have been produced and converted successfully. However, there were some limitations as lower productivity and higher steam consumption. All these drawbacks are linked with the slow drainage properties of steam exploded wheat straw pulp. Slow drainage leads to lower dryness after pressing and thus longer drying time. Optimisation of these properties through appropriate additives could increase the profitability of the product. Nevertheless, attention should also be paid to dimensional stability and recycling potential of papers made from steam exploded wheat straw pulp and waste papers.

From the data obtained for banana and *Cynara Cardunculus* pulps, two concluding remarks could be drawn: all other mechanical properties fall into the range of the values for other annual plant and the values of RCT, CMT and FCT found for basis weight of 136 g/m^2 were higher than those found for suitable material for corrugated boards production. Although the fact that these results are very encouraging, we can consider this study only a preliminary approach, since these raw materials could be used as alternative sources of fibres even though much more investigation is needed to optimise their cooking and converting processes.

REFERENCES

1. Watson P.A., Bicho P.A., wheat straw a viable fibre source for Canada? 84th CPPA annual meeting, technical section , 27–30 january, Montreal, Canada, pp B371–B374, 1998.
2. Yilmaz Y. lime soda oxygen (LSO) pulping of wheat straw-part 2 : effect of cookingparameters on paper properties. Paperi ja Puu, vol.77, n°8, pp 498–501, 1995.
3. Hurter A.M., utilization of annual plants and agricultural residues for the production of pulp and paper. Tappi pulping conference, 30 October-2 November, New Orleans, USA, vol.1, pp 139–160, 1998.
4. Erođlu H. *Soda-oxygen pulping of wheat straw* Tappi Nonwood Plant Fiber Pulping Progress Report n° 14, pp 99–106, 1983.
5. Rydhom S.A. Pulping processes, interscience Publishers, New-york, USA, p1269, 1965.
6. Robson D., Hague J. *The properties of straw fibers,* PIRA “Straw - a valuable raw material”, 20–22 April, Cirencester, UK, vol. 1, paper 03, 1993.
7. Misra D.K. *Cereal straw,* Pulp and Paper Manufacture, 3rd ed., vol. 3, “Secondary fibers and nonwood pulping”, pp 82–93, 1987.
8. Atchison J.E. *Nonwood fiber could play a major role in future US papermaking,* Pulp and Paper, vol. 69, n° 7, pp 125–128, 130–131, 1995.
9. Darkwa N. A. Plaintain pseudostem-a fibre source for tropical countries, Pulping Conferences, Tappi proceedings, pp 645–649, 1998.
10. Antunes, A., Amaral, E., Belgacem, M. N.,. *Cynara cardunculus* L.: chemical composition and soda-anthraquinone cooking. Industrial Crops and Products 12, 85–93, 2000.
11. Antunes, A., Belgacem, M. N., Silvy J., Properties of pulps and papers from cynara cardunculus L, Cellulose Chem. Technol. In press, 2003.
12. Antunes, A., Amaral, E., Costa, A., Silvy, J., Belgacem, M. N., 1999. *Cynara cardunculus*: a new source of cellulosic fibres for paper. In: Proceedings of the XIth International Symposium on Cellulose Chemistry and Technology, September 1999, Iasi, Romania, pp. 151–156.
13. Mamers H., Yuritta J.P., Menz D.J. *Explosion pulping of bagasse and wheat straw.*Tappi Journal, vol. 64, n° 7, pp 93–96, 1981
14. Cassat D. *Production de pâte ŕ papier ŕ partir de plantes lignocellulosiques et pâte ŕ papier obtenue* Patent FR 2 743 579, 1998.
15. Schott S., Chaussy D., Mauret E. “utilisation of straw for production of pulp and paper” Paperi ja Puu-Paper and Timber, vol.83, n°6, 2001, p 453–457.
16. Schott S, Valorisation de la pâte de paille de blé, obtenue par le procédé d’explosion en phase vapeur, pour une application en papeterie. Thesis of the ‘Institut National Polytechnique de Grenoble’ France, 2000.
17. De Choudens, C., Angelie, R., 1996. The bivis process and the annual plants (wheat straw and fibre sorghum) for the manufacture of pulps for packaging paper. In: Proceedings of the IVth European Workshop on Lignocellulosics and Pulp, September 1996, Stressa, Italy, p.124–131.