Pulp produced from decorticated abaca fiber

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ABSTRACT

The objective of the study was to examine the potential of decortication as an alternative means of extracting abaca fiber for production of abaca pulp. Decorticated fibers were compared with commercially stripped abaca fiber. Results were evaluated in terms of fiber recovery, physical–chemical–morphological properties, and pulp quality. The results demonstrate that decorticated abaca fiber produces a high-quality pulp comparable with that from more expensive, commercially stripped fibers. The differences in pulp quality reflect the fact that decortication provides a higher fiber yield and a lower degree of fiber purification.

ABACA (*MUSA TEXTILIS*) FIBER, also known as Manila hemp, is obtained from the leafsheath of a banana-like plant grown mainly in the Philippines. The country annually produces an average of 60,000 metric tons of abaca fiber, representing about 85% of world abaca production. Of this quantity, 40% is exported in the form of raw fiber, which is eventually processed principally into pulp for specialty papers. The rest is processed in the Philippines into pulp, ropes and twines, yarns and fabrics, and fibercrafts. These abaca products are also chiefly exported *(1)*.

Abaca is an excellent raw material for the manufacture of specialty papers. Its long fiber length, high strength, and fineness make it a superior material for the production of thin, lightweight papers of high porosity and excellent tear, burst, and tensile strengths *(2)*.

The quality of abaca pulp is affected by several factors, the most important being the type of cleaning, which determines the grade of fiber. The type of pulp produced depends mainly on the fiber grade. Excellent fiber grades (I, S_2, or G) are made into pulp for very porous and high-strength specialty tissues, such as tea-bag papers and meat casings. The fair-to-residual grades (JK through Y2) are made into pulp for specialty papers with high tear and tensile strengths, such as vacuum bags and wrapping papers *(3)*.

The quality of cleaning is influenced by the process used to extract the fiber. The available process options are either manual (handstripping) or mechanical (spindle stripping) *(4)*. Abaca fibers are stripped from the plant's leafsheath, which contains primary (stronger and longer) and secondary (weaker and shorter) fibers. The primary fibers are located in the outer part of the leafsheath, while the secondary fibers are found in the inner part. In both the handstripping and spindle-stripping processes, only the primary fibers are extracted for use. The secondary fibers remain intact in the residual leafsheath, which is discarded as plantation waste. The tuxying process is used to separate the primary fibers from the secondary fibers. In this process, a knife is inserted between a section of the outer and the inner parts of a leafsheath. The outer section, which contains the desirable fibers, is then peeled away from the rest of the leafsheath. The separated outer section is called tuxy.

Another fiber-separation process is decortication, where the whole leafsheath is used, thereby producing a mixture of the primary and secondary fibers. Decortication is not used to extract abaca fiber on a commercial scale, although this has been attempted in the past *(5)*.

There are clear economic incentives for attempting to develop a commercially viable decortication process as an alternative method of fiber extraction for production of abaca pulp. Studies on abaca fiber separation show that handstripping yields an average of 1.2% of fiber based on the weight of the stalk, with an average daily output of 10 kg. Spindle stripping gives an average of 1.75% fiber recovery, with an average daily output of 32 kg. Decortication is expected to yield higher fiber recovery and higher output rate.

EXPERIMENTAL PROCEDURES

Decortication of abaca fiber

Abaca stalks (*tinawagan puti* variety) were gathered from the farm maintained by the Institute of Plant Breeding at the University of the Philippines (Los Banos). Two types of materials were decorticated during the experiments:

1. Whole leafsheath (containing both primary and secondary fibers)
2. Residual leafsheath after tuxying (containing secondary fibers and vegetable tissues that normally would be discarded as plantation waste).

All materials were weighed before feeding to a conventional ramie decorticator, which was powered by a 10-hp diesel engine. The materials were then fed one piece at a time to the decorticator. Extraction time was recorded for each trial. The fibers were air-dried, and the weight

KEYWORDS
chemical properties, cleaning, epidermis, extraction, fiber recovery, fiber structure, fibers, helices, manila hemp, parenchyma, physical properties, pulps, quality, stock preparation, virgin pulps.

was taken at moisture content of 9.6%.

Prior to pulping, fiber samples were taken for chemical and morphological analyses.

Pulping of decorticated abaca fiber

Both types of decorticated materials were pulped using the alkaline sulfite process in an air-heated multidigester with six autoclaves. Each autoclave has a maximum capacity of 2.5 L. Pulping conditions are given in **Table I**.

At the end of the cooking cycle, the pulp was thoroughly washed, disintegrated, screened, and manually shredded. Pulps were tested using the following TAPPI test methods: T 624 cm-85 "Analysis of soda and sulfate white and green liquors," T 625 cm-85 "Analysis of soda and sulfate black liquor," T 236 cm-85 "Kappa number of pulp," T 200 om-89 "Laboratory processing of pulp (beater method)," T 227 om-92 "Freeness of pulp (Canadian standard method)," T 205 om-88 "Forming handsheets for physical tests of pulp," T 220 om-88 "Physical testing of pulp handsheets."

For comparison purposes, commercial-grade spindle-stripped abaca fibers (excellent grade S_2 and fair grade JK) were pulped under the same conditions as the decorticated abaca fiber. Both of the spindle-stripped pulps were evaluated using the same test methods.

Chemical charge	14% Na_2SO_3 + 4% Na_2CO_3
Liquor:material ratio	4:1
Temperature (T_{max}), °C	170
Time to T_{max}, h	1.5
Time at T_{max}, h	2.0

I. Pulping conditions for abaca

RESULTS

Decortication

Residual leafsheath. Using the residual leafsheath, fiber recovery after decortication was equivalent to 1.1% of the fresh weight of the test material. Fiber production was recorded at 17.7 kg for an 8-h work shift. In terms of fiber recovery, decortication of residual leafsheath was 0.1 percentage point lower than the handstripping process and 0.6 percentage point lower than the spindle-stripping process. In terms of fiber output, decortication of residual leafsheath was 76.8% higher than the handstripping process but 50.5% lower than the spindle-stripping process.

Whole leafsheath. Decortication of the whole leafsheath of abaca produced higher fiber recovery and higher output. The fiber recovery of 2.6% was 1.4 percentage points higher than the handstripping process and 0.9 percentage point higher than the spindle-stripping process. The output of 47.9 kg for an 8-h work shift was 378.9% higher than the handstripping process and 49.7% higher than the spindle-stripping method of fiber separation.

The higher fiber recovery for the decortication process is attributed to the extraction of the shorter and weaker fibers in the residual leafsheath. In the spindle-stripping process, the residual leafsheath is not stripped but, rather, is left to decompose in the field as plantation wastes. The higher production for the decorticated whole leafsheath demonstrates that decortication is more efficient than spindle-stripping as a method of fiber extraction.

Fiber quality

Previous studies of pulps produced from decorticated whole-leafsheath abaca fibers have shown them to contain a high percentage of parenchyma cells and helices. The helices have been described as the "thin threadlike spiral thickness of the vessels" *(6)*.

We undertook a microscopic study to determine the levels of helices, parenchyma cells, and epidermal strips in abaca fibers extracted using the three cleaning methods (decortication, spindle-stripping, and handstripping). The results showed that decorticated fibers contain higher levels of helices and epidermal strips. On the other hand, decorticated fiber contains fewer parenchyma cells than does excellent-grade (EF) fiber produced from either spindle-stripping or handstripping.

The chemical and physical properties of abaca pulp are likewise affected by the type of cleaning, as seen in **Table II**. Decorticated abaca fiber had higher extractives than spindle-stripped abaca fiber. The decorticated whole leafsheath and the residual leafsheath had solubilities of 2.4% and 2.7% in alcohol–benzene, respectively. In contrast, the alcohol–benzene solubilities for the spindle-stripped S_2 and JK grades were much lower, 0.8% and 1.9%, respectively. Hot-water solubles also were higher for the decorticated fibers, with levels of 4.1% and 4.3% for whole leafsheath and residual leafsheath, respectively. The hot-water solubles for grades S_2 and JK were 1.7% and 2.0%, respectively. The same trend was observed for solubility in 1% NaOH. Decorticated abaca fiber had solubles of 21.0% and 21.2% for the whole leafsheath

	SPINDLE-STRIPPED		DECORTICATED	
	Excellent cleaning (S_2)	Fair cleaning (JK)	Whole leafsheath	Plantation wastes
Chemical properties				
Alcohol benzene solubility, %	0.8	1.9	2.4	2.7
Hot-water solubility, %	1.7	2.0	4.1	4.3
1% NaOH solubility, %	13.9	19.6	21.0	21.2
Ash, %	1.0	2.4	2.5	3.1
Lignin, %	16.5	17.6	10.4	8.5
Holocellulose, %	88.5	71.8	91.3	86.3
Hemicellulose, %	23.0	19.4	14.0	27.5
Physical properties				
Tensile strength, kg/g/m	43.3	38.0	32.6	30.6

II. Physical and chemical properties of spindle-stripped and decorticated abaca

	SPINDLE-STRIPPED		DECORTICATED	
	Excellent cleaning (S_2)	Fair cleaning (JK)	Whole leaf-sheath	Plan-tation wastes
Unbeaten				
Freeness, mL CSF	729	693	614	520
Basis weight, g/m^2	62.3	60.4	63.8	57.2
Burst strength, kPa	90.9	129.3	149.5	149.2
Breaking length, km	8.0	9.2	16.4	15.3
Tear strength, mN	637.4	788.6	208.3	169.6
Air resistance (Gurley porosity), s/100 mL	0.5	1.3	7.4	31.9
Beaten (20 min)				
Freeness, mL CSF	416	386	277	225
Basis weight, g/m^2	63.9	64.5	50.9	57.1
Burst strength, kPa	136.7	143.3	148.0	117.9
Breaking length, km	11.8	11.1	15.7	14.6
Tear strength, mN	308.0	483.8	171.1	115.5
Air resistance (Gurley porosity), s/100 mL	15.5	85.2	137.6	914.3

III. Characteristics of unbeaten and beaten abaca pulps produced from spindle-stripped and decorticated fibers

and residual leafsheath, respectively. In comparison, grades S_2 and JK had 13.9% and 19.6% solubles in 1% NaOH. A similar trend was observed with regard to ash content. Decorticated fiber had ash contents of 2.5% and 3.1% for the whole leafsheath and residual leafsheath, respectively. Grades S_2 and JK had 1.0% and 2.4% ash content, respectively.

The results showing that decorticated fiber had a lower lignin content (10.4% for decorticated fiber from whole leafsheath vs. 16.5% for S_2 and 17.6% for JK) and a higher holocellulose content (91.3% for decorticated whole leafsheath vs. 88.5% for S_2 and 71.8% for JK) are inconclusive. Using the same sample material, the decortication process would be expected to produce fiber with higher lignin content and comparable holocellulose content, since decorticated fiber includes secondary (weaker and shorter) fibers and their nonfibrous tissues. In this test, the inconclusive result obtained for lignin and holocellulose contents may be due to the fact that the test materials for excellent (S_2) and good (JK) fibers came from commercial baling establishments, where the fibers are of mixed varieties. For the decorticated fiber, we used the *tinawagan puti* variety, which is

one of the superior varieties of abaca.

Pulp quality

The test results in Table III show that decorticated abaca fiber produces pulp that is less free (614 mL CSF for whole leafsheath compared with 729 mL CSF for S_2, and 693 mL CSF for JK), less porous (7.4 s for whole leafsheath vs. 0.5 s for S_2, and 1.3 s for JK), and lower in tear strength (208.3 mN for whole leafsheath vs. 637.4 mN for S_2 and 788.6 mN for JK). On the other hand, pulp produced from the decorticated fiber had higher burst strength (149.5 kPa for whole leafsheath vs. 90.9 kPa for S_2 and 129.3 kPa for JK) and tensile strength (16.4 km for whole leafsheath vs. 8.0 km for S_2 and 9.2 km for JK). The higher burst and tensile strengths for the pulp from decorticated abaca fiber may be due to the high concentration of parenchyma cells and helices, which serve as fillers in the pulp. Its low porosity may also be due to the presence of these nonfibrous materials, which would tend to block the passage of air through the sheet.

CONCLUSIONS

Our research confirms earlier studies, which found that decorticated abaca can be used for paper products where strength is a requirement and porosity is of less concern.

Because decortication is the most efficient means of extracting abaca fiber, it should make abaca fiber more attractive for use as a high-strength extender for softwood pulp. However, the fiber extracted by decortication is not suitable for use in production of thin tissues. To that end, the process needs further improvement to reduce or eliminate helices from the extracted fiber. **TJ**

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Presented at the "Workshop on High Grade Pulp, Alkaline Paper Making and Waste Paper Recycling," sponsored by the United Nations Development Program (UNDP), United Nations Industrial Development Organization (UNIDO), and the Forest Products Research and Development Institute (FPRDI), Laguna, Phillipines, July 1992.

Received for review Nov. 10, 1993.

Accepted April 28, 1995.

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