The Papermaking Properties Of Waterhyacinth

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ABSTRACT

Waterhyacinth plants (*Eichhornia crassipes* (Mart.) (Solms) from Lake Alice and the polishing pond of the sewage plant of the University of Florida were chopped, passed through an attrition mill, and over a travelling screen belt through which most of the leaf, root and pith were washed, leaving a relatively clean residue of vascular fiber bundles. These fiber bundles were cooked by four chemical processes, ranging from highly alkaline to mildly acid. Yields of pulp from the fiber bundles were in the commercially acceptable range but, on a basis of the whole waterhyacinth plant, were extremely low. The freeness values (drainage rates)

[1]Sponsored by Department of Natural Resources, State of Florida.

of all waterhyacinth pulps were so low as to make it impossible to consider these pulps to have any salable value to the paper industry.

INTRODUCTION

This research study was part of an over-all investigation of possible salable products from waterhyacinth plants harvested from the lakes and streams in Florida. The sources of waterhyacinth used in the study were Lake Alice and the polishing pond of the sewage treatment plant, both on the University of Florida campus.

A thorough search of the pulp and paper literature disclosed no publications on efforts to convert waterhyacinth to paper pulp. However, the physical structure of the stalk of the plant, consisting of a concentration of vascular fiber bundles in the outer wall and a mixture of pith and fiber in the interior, is somewhat similar to the structure of sugar cane *(Saccharum officinarum* L*)* bagasse. Since earlier research on the pulping of bagasse at the Florida laboratory had proved this sugar cane waste to be a valuable source of paper pulp (2, 3), it was decided to use the same procedures for separating the vascular fiber bundles from the pith, leaf and root of the waterhyacinth plants that had been used successfully in bagasse processing.

It was recognized that this separation of vascular fiber bundles would be more difficult for the waterhyacinth plants than for bagasse because the waterhyacinth plant consists of root, stalk and leaves, in contrast to bagasse, made up almost entirely of pressed stalk. Preliminary testing of the waterhyacinths to be used in the research showed the plants taken from Lake Alice to consist of 43.7% stalk, 35.6% root and 20.7% leaf, while those taken from the polishing pond of the sewage plant were made up of 52.8% stalk, 22.4% root and 24.8% leaf.

METHODS AND MATERIALS

The following processing steps were used to bring about the separation of the vascular fiber bundles from the waterhyacinth plants and conversion of the vascular fiber bundles into pulp.

1. Chopping the plants in a forage chopper to cut the stalks into lengths of 1.7 cm.
2. Passing the chopped material through an attrition mill to reduce roots and leaves to very small pieces and break the physical bond between fiber bundles and pith.
3. Passing the milled product over a traveling screen belt where high pressure water sprays wash the fines from the fiber mat laid down on the screen. The clean fiber bundles are discharged at the end of the screen, dried and stored for later pulping experiments.
4. Reducing the fiber bundles to individual fiber by chemical pulping in the experimental digesters, converting the pulps into paper handsheets and testing these paper sheets for physical properties.

Chopping and Pressing of Waterhyacinth: The forage chopper at the Department of Agricultural Engineering was used for cutting the plants and, in some instances, the Vinson press at the same location was used for dewatering the chopped material.

Comparatively small amounts of waterhyacinth plants (maximum of two pickup truck-loads) were processed at any one time as the wet material will begin to decompose in 3 days.

Attrition Milling: The mill used for this operation is the 74.6 KW (100 h.p.) Vertiflex mill, equipped with toothed plates, manufactured by Beloit Corp., Jones Div., at Dalton, Mass. The mill consists of a rotor and stator, 71 cm (28 inches) diam., mounted in a horizantal plane. The bottom, rotor plate operates at 1800 rpm. The teeth on each plate are arranged in circular rows in such a manner that each row of teeth on the rotor is centered between two rows of teeth on the upper, stator plate. The rotor can be moved vertically from a position where the tips of the rotor teeth touch the root between rows of stator teeth (zero clearange) to a position where the tips of the rotor teeth are in the same horizontal plane as the tips of the stator teeth (maximum clearance). Plate clearance is defined as the distance between the tips of the rotor teeth and the root between adjacent rows of stator teeth.

Chopped waterhyacinth is fed by a conveyor belt 30.5 cm (12 inches) wide to the top of the attrition mill, through a 22.9 cm (9 inch) diam. hole in the center of the stator plate, and falls directly onto the center of the rotor plate. Flinger bars at the center of the rotor distribute the material evenly across the rotor plate. Rate of feed to the machine is adjusted by raising or lowering rotating paddles which control thickness of the layer of feed on the conveyor belt. When paddles are at maximum height above the belt, the layer of feed is 5.1 cm (2 inches) thick. It is possible to adjust feed rate to one-fourth, one-half, or three-fourths of full feed opening.

In milling the chopped waterhyacinth it is necessary to adjust feed rate and plate clearance to obtain a product which, upon washing, will yield the maximum amount of clean fiber bundles with a minimum of pith and fragments of root and leaves. To arrive at optimum milling conditions, a rapid screen washing test on small milled samples was used. The test involves the use of a 20 cm (8 inch) diam. Tyler Standard screen with 1.00 mm openings and 0.58 mm wire diam. (16 mesh Tyler Standard) and a hand-operated spray nozzle. The procedure was fully described in an earlier publication (3).

Optimum milling conditions for the chopped waterhyacinth were found to require one-half of maximum feed rate and a plate clearance ranging between 0.41 and 0.61 cm. The rapid Tyler screen washing test on the product showed 18.5% of clean fiber, 81.5% fines passing through the screen. However, when the chopped waterhyacinths were dewatered in the Vinson press to 85% water, the material became quite tough and stringy, requiring a plate clearance of 0.20 cm at the same one-half of maximum feed rate. The washing test on this product showed it to contain 31% clean fiber, 69% fines.

Washing the Milled Waterhyacinths: The travelling screen belt used for washing the milled material has been described in an earlier publication on the processing of bagasse (2). However, the screen belt now being used on the machine is an Ashworth Bros. balanced weave conveyor belt No. B-84-84-22.

In operation, the milled waterhyacinths are spread evenly at the head end of the screen and puddled by hand to break up lumps and insure that the fiber bundles lie flat on the screen. As the material passes under the sprays, pith, broken root and leaf and dirt are washed through the thin fiber mat and are discharged into a small tank for possible recovery of solids for fodder or soil additive. Clean fiber bundles discharge at the end of the screen, are collected in trays, dried and stored for later pulping tests.

Pulping and Pulp Testing: Operation of the experimental digesters and cooking procedure for wood pulping have been described in an earlier publication (1). However, with the very bulky waterhyacinth fibers, only 700 g of dry material could be charged in a digester, in contrast to the 4000 g capacity for wood chips. Also, the highly absorbent waterhyacinth fiber required 8 to 12 g of cooking liquor per g of dry fiber, compared to the 3.5 to 4.0 g required in wood pulping.

Four different cooking processes were used in pulping the waterhyacinth fiber bundles. Initial concentration of cooking chemical, liquor-to-wood ratio, max cooking temperature, time to and time at max cooking temperature for each process are listed below:

1. Pulping with sodium sulfite: initial concentration, 70 g Na_2SO_3 per liter; liquor ratio, 7:1; max temperature, 135 to 172 C; time to max temperature 30 min, time at max temperature, variable.
2. Pulping with sodium hydroxide: initial concentration, 25 g NaOH per liter; liquor ratio, 7:1; max temperature, 121 to 148 C; time to max temperature, 16 and 30 min; time at max temperature variable.
3. Pulping with mixtures of sodium sulfite and sodium bisulfite: initial concentration, $NaHSO_3$, 36.4 and 36.8 g per liter and Na_2SO_3 variable between 10 and 35 g per liter to control initial pH between 5.2 and 6.2; liquor ratio, 12:1; max temperature 156 and 162 C; time to max temperature, 30 min; time at max temperature, variable.
4. Pulping with a mixture of sodium hydroxide and sodium sulfide (kraft process): initial concentration, 35 g equivalent Na_2O per liter, 25% sulfidity; liquor ratio, 12:1; max temperature, 121 and 156 C; time to max temperature, 15 and 30 min; time at max temperature, variable.

The usual procedure for screening the cooked pulps on the Valley flat screen (1) could not be used for the waterhyacinth pulps. The cooked pulps, instead of being reduced to individual fibers in the digesters, were discharged as fiber bundles held loosely together and would not pass through the slots in the flat screen. Therefore, only total yield was evaluated by washing and processing the total material blown from the digesters in the same manner as described for determining screened yield for wood pulps (1).

Prior to the formation and testing of paper handsheets from an experimental pulp, it is necessary to develop fiber strength in the Valley Niagara beater according to TAPPI Standard T 200 (4). Preliminary tests on the waterhyacinth pulps indicated that these pulps are extremely sensitive to the mechanical action of the beater, requiring modifications in the time intervals of beating recommended by the TAPPI Standard. For example, instead of the 10 min time interval recommended for mixing the pulp in the beater tub with no pressure between the beater roll and the bedplate, it was found that 2.0 min of mixing not only reduced the waterhyacinth fiber bundles to individual fibers but also provided a uniform suspension of pulp in the beater. Also, the beating time intervals at which pulp samples were removed for evaluation had to be reduced to 3, 6, 9 and 12 min, instead of the 15 min intervals up to a total time of 40 min for pine kraft pulps.

At each time interval, the pulp sample removed from the beater is first tested for freeness (drainage rate). TAPPI Standard T 227 (4) describes the method used for determining Canadian Standard freeness, measured in ml.

The first tests of freeness of waterhyacinth pulps, after mixing only 2 min in the beater with no weight on the bedplate, showed very low freeness values of 40 to 80 ml, in contrast to unbeaten freeness values for pine kraft pulp of 700 to 750 ml. After 12 min beating time, most of the waterhyacinth pulps had freeness values of 25 to 40 ml.

In an attempt to improve freeness by removal of gummy fines resulting from the small amounts of pith and leaf fragments in the material charged to the digester, several experiments were made on some of the pulps to remove these fines on a Sweco vibrating screen, using screens of 100, 200 and 325 mesh. These tests showed no promise of significantly improving drainage rate and were discontinued.

Handsheets for physical testing of waterhyacinth pulps, beaten for the time intervals described above, were made according to TAPPI Standard T 205 (4), with the exception that a Valley Standard sheet mold was used instead of the sheet mold described in the standard. The only difference in the two molds is the size of the sheet produced. The Valley mold makes a sheet 19.7 cm diam., compared to 16.5 cm for the standard.

The procedures described in TAPPI Standard T 220 (4) were followed in determining the physical strength of waterhyacinth handsheets and calculating strength values in tear, burst and breaking length (tensile strength). Strength values for five duplicate handsheets for each beating time were averaged and these average values were plotted against beating time.

In a final effort to produce the best possible waterhyacinth pulp, all leaves and roots were cut by hand from two truck-loads of plants. The stalks were then processed in exactly the same manner as previously described for the whole plants. The processed stalks were cooked by the sodium sulfite process. Total yield and physical characteristics of the resultant pulps were evaluated.

Properties of paper sheets made from mixtures of a commercial pine kraft pulp and waterhyacinth pulp made from the stalks were evaluated. Freeness and physical strength were measured for 100% pine kraft, mixtures of

TABLE 1. Sodium Sulfite Cooking of Depithed Waterhyacinth.

Cook no.	Max temp C	Total Cooking Time (min)	Total Yield (% of original fiber)
4343	162	50	63.1
4344	162	70	58.4
4345	172	30	64.1
4346	172	40	55.6
4347	172	60	52.5
4351	135	30	83.9
4352	135	45	80.8
4353	135	60	71.8
4354	156	30	79.4
4355	156	45	70.0
4356	156	55	66.7
4357[a]	156	45	64.9
4358[a]	162	45	63.4
4392[b]	156	45	67.6
4393[b]	156	45	69.0

[a]Cooks 4357 and 4358 consisted of three duplicate cooks.
[b]Cooks 4392 and 4393 used waterhyacinth stalks from which root and leaves had been removed before decortication and depithing.

65% pine kraft, 35% waterhyacinth pulp and 50% pine. 50% waterhyacinth pulp.

RESULTS

Pulping data for the thoroughly washed vascular fiber bundles from the waterhyacinth plants cooked with sodium sulfite, sodium hydroxide, mixtures of sodium sulfite and bisulfite, and conventional kraft liquor (75 mole % sodium hydroxide, 25 mole % sodium sulfide) are listed in Tables 1 through 4, respectively. The tabulated data for each cooking process show the effects of variations in max temperature, time to max temperature and total cooking time on percent yield of pulp from the fibrous material charged to the digesters.

Physical strength data and Canadian Standard freeness, as functions of beating time, were evaluated for representative pulps cooked by each of the chemical processes studied. From these results, the best pulp cooked by each process was selected for graphical presentation. Figures 2A and 2B show physical strength and freeness values vs. beating time for the sulfite pulps made from whole waterhyacinth plants and from the stalks alone and for the sulfite-bisulfite pulp.

TABLE 2. Sodium Hydroxide Cooking of Depithed Waterhyacinth.

Cook no.	Max temp C	Cooking time (min) To max temp	Cooking time (min) Total	Total yield (% of original fiber)
4359	148	30	30	49.0
4360	148	30	40	47.0
4361	148	30	50	46.9
4362	139	30	30	48.6
4363	139	30	40	46.9
4364	139	30	50	44.4
4365	121	16	16	60.0
4366	121	16	21	55.6
4367	121	16	26	55.2

Figures 3A and 3B are similar plots for sodium hydroxide and kraft pulps made from whole plants.

The strength and freeness values vs. beating time for pine kraft and for mixtures of pine kraft and sodium sulfite waterhyacinth pulp made from stalks alone are shown in Figures 1A and 1B.

DISCUSSION

Separation of Vascular Fiber Bundles from the Waterhyacinth Plants: Several tests to determine yield of dry fiber bundles from the original waterhyacinth plants, after milling and washing on the travelling screen, showed that 18 to 20% of the original plants was recovered as fairly clean fiber. This was in very good agreement with the 18.5% recovered in the rapid Tyler screen test.

When the raw material fed to the attrition mill had been passed through the Vinson press after the chopper,

TABLE 4. Kraft ($NaOH + Na_2S$) Cooking of Waterhyacinth.

Cook no.	Max temp C	Cooking time (min) To max temp	Cooking time (min) Total	Total yield (% of original fiber)
4386	156	30	30	44.5
4387	156	30	40	43.5
4388	156	30	50	41.5
4389	121	15	15	51.3
4390	121	15	25	47.9
4391	121	15	40	45.3

TABLE 3. Sodium Sulfite-Bisulfite Cooking of Depithed Waterhyacinth.

Cook No.	Max temp C	Liquor concn (g SO_2 per liter) as $NaHSO_3$	Liquor concn (g SO_2 per liter) as Na_2SO_3	Initial pH	Total cooking time (min)	Total yield (% of original fiber)
4374	156	36.8	35.4	6.2	30	88.6
4375	156	36.8	35.4	6.2	40	83.7
4376	156	36.8	35.4	6.2	55	74.5
4377	156	36.8	12.0	5.5	30	78.6
4378	156	36.8	12.0	5.5	45	74.3
4379	156	36.8	12.0	5.5	65	70.7
4383	162	36.4	9.5	5.2	30	84.9
4384	162	36.4	9.5	5.2	50	74.6
4385	162	36.4	9.5	5.2	70	67.5

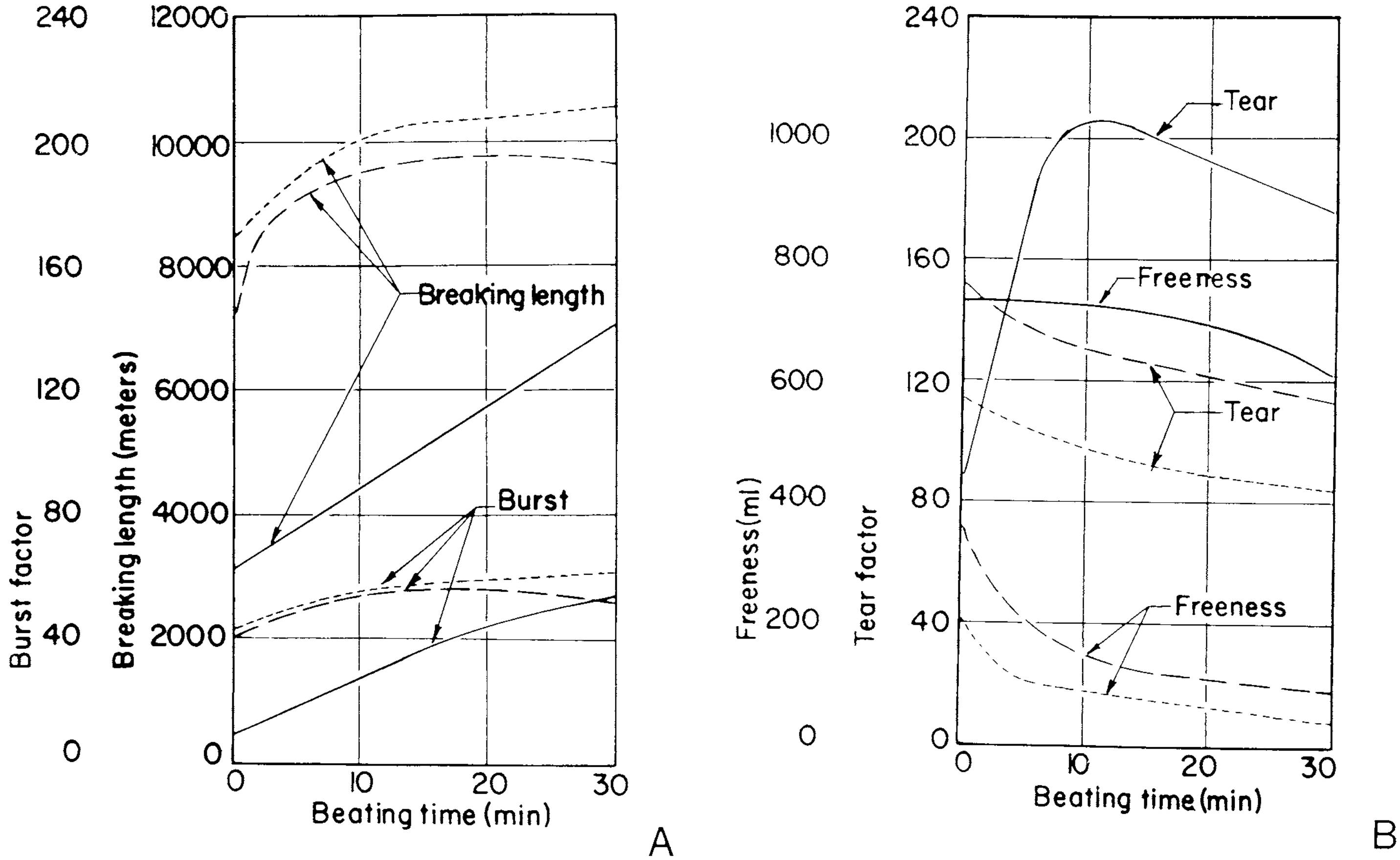

Figure 1. Physical characteristics of pine kraft and mixtures of pine kraft and sulfite waterhyacinth pulps. —— · —— 100% pine; — — — — — 65% pine, 35% waterhyacinth; - - - - - 50% pine, 50% waterhyacinth.
A. Burst factor and breaking length vs. beating time.
B. Tear factor and freeness vs. beating time.

the resultant yield of washed fiber bundles amounted to 30 to 33% of the pressed material. This increase in yield, however, is not on a basis of the whole waterhyacinth plants. It had been observed during the pressing operation that the liquid discharged from the Vinson press contained a rather heavy load of pith and dirt. The weight of this material lost during pressing was not measured but it probably accounts for the increased yield to the 30% range. Therefore, it should be considered that not over 20% of the whole waterhyacinth plant can be recovered as raw material fed to the pulp digesters.

It had been hoped, originally, that the 80% of the waterhyacinth washed through the travelling screen, consisting of pith, root, leaves and some fine fiber, could be used as animal fodder or soil additive. However, when it was subsequently found that the vascular fiber bundles could not be converted to salable pulp, evaluation of the screen fines as salable products was abandoned.

Pulping of Washed Fiber Bundles: Pulping with sodium sulfite and with mixtures of sulfite and bisulfite (Tables 1 and 3) resulted in the highest yields, as high as 80 to 88% of material fed to the digesters. However, at yields higher than 75%, pulps were undercooked and could not be converted into papers of acceptable strength. The highly alkaline processes, using sodium hydroxide and kraft liquors (Tables 2 and 4) resulted in pulps of much lower yields, mostly in the range of 40 to 50%.

Pulp yields of 65 to 75% resulted in paper handsheets of reasonably high strength. These apparently high yields, when converted to percentages of the original waterhyacinth plant, were reduced to the very low values of 13 to 15%, since only a max of 20% of the whole plant was available to the pulping operation.

The cooked vascular fiber bundles, when blown from the digester, did not reduce to individual cellulose fibers but remained as soft, loosely bound fiber bundles. A method had to be developed to reduce these fiber bundles to individual fibers, without fiber cutting, before the pulps could be converted into paper handsheets or evaluated for freeness. It was found that rapid agitation of a water suspension of the cooked fiber bundles reduced them completely into individual fibers. Further investigations showed that the Valley Niagara beater (4) could be used to provide the necessary agitation. Only 2 minutes of mixing in the beater, with no pressure between the roll and the bedplate was required to bring about complete reduction to individual fibers.

Pulp Freeness: Canadian Standard freeness of a pulp is a measure of drainage rate, a very important variable in papermaking, where a pulp suspension of only 0.5% fiber

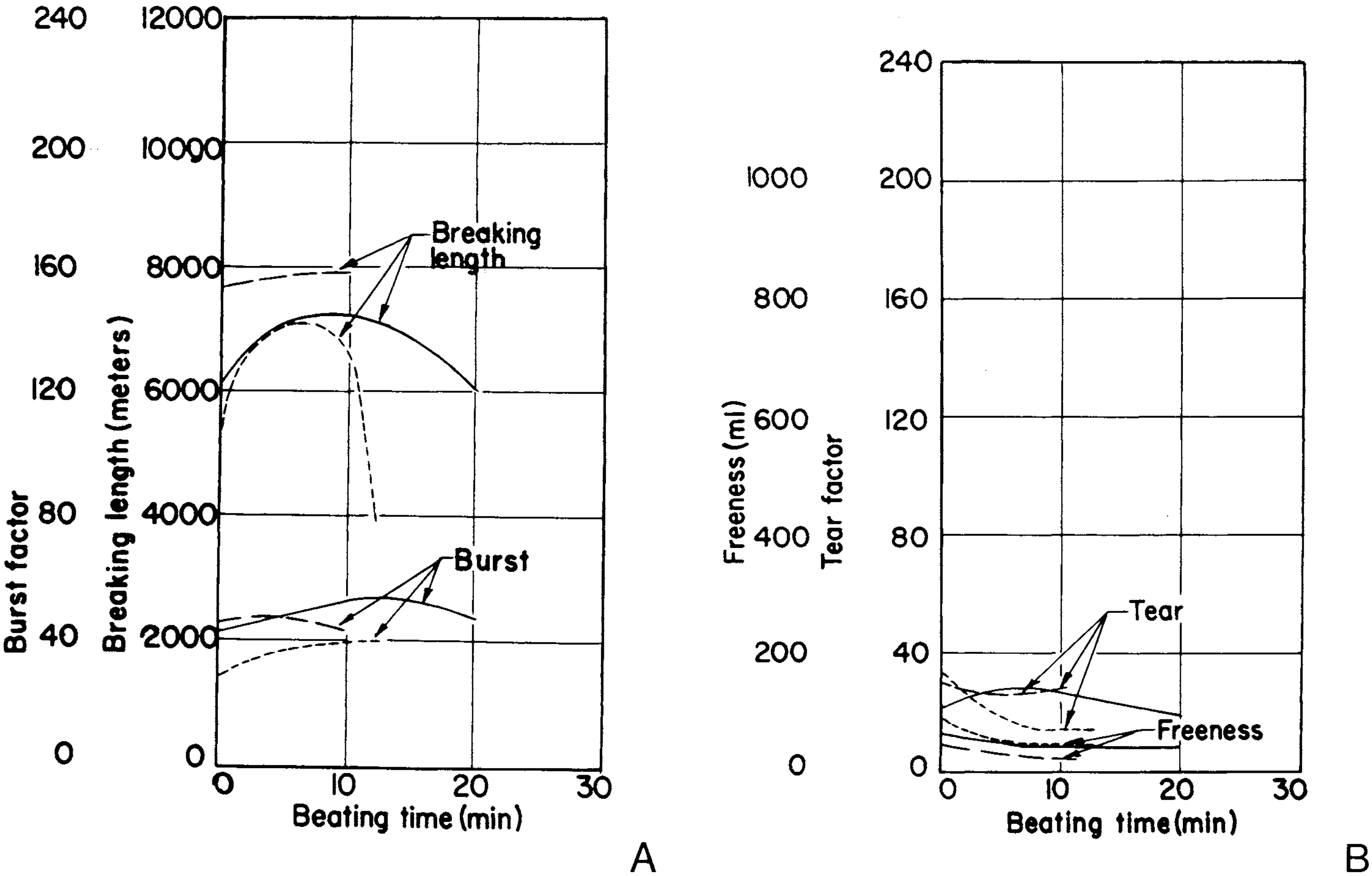

Figure 2. Physical characteristics of sodium sulfite and sulfite-bisulfite waterhyacinth pulps. ———— sulfite pulp No. 4357; — — — — — sulfite pulp No. 4392; - - - - - sulfite-bisulfite No. 4376.

A. Burst factor and breaking length vs. beating time.
B. Tear factor and freeness vs. beating time.

must be drained to a wet paper mat on the paper machine fourdrainer wire screen travelling at 300 to 600 m per min. Liner board grades of pine kraft pulp have an unbeaten freeness of 700 to 750 ml and required fiber strength is developed by beating to a freeness of 450 to 600 ml before being pumped to the paper machine.

The waterhyacinth pulps, cooked by each of the four chemical processes studied, resulted in extremely low freeness values in the range of 35 to 90 ml. After processing in the Niagara beater to develop fiber strength, freeness was in the range of 25 to 40 ml. The extremely low drainage rates corresponding to these freeness values would make the pulps unacceptable to the paper industry even if fiber strengths had been found to be superior to those of pine pulps.

Efforts were made to improve drainage rates of the pulps by washing out gummy fines created by the small amounts of pith and leaf fragments in the material charged to the digesters. Several pulps were thoroughly washed on a 45.7-cm dia Sweco vibrating screen, using Tyler Standard screens of 100, 200 and 325 mesh. For example, one pulp was washed on the 200 and 325 mesh screens in series, with the result that 82% of the pulp was retained on 200 mesh, 4% on 325 mesh and 14% passed through the 325 mesh screen. The untreated pulp had a freeness of 49 ml, while the 200 mesh fraction, with 18% of the pulp removed as fines, had a freeness of only 79 ml, very little improvement. When a 100 mesh screen was substituted for the 200 mesh, freeness of the washed pulp improved slightly and percentage of fines lost through the screen did not increase significantly. It therefore appears that the very low drainage rates of the waterhyacinth pulps is not due to contaminants such as pith and leaf fragments but may be caused by the characteristics of the fibers themselves.

As a check on the waterhyacinth fibers and the cementing material holding the fibers together in the vascular fiber bundles, dried stalks from which all leaf and root had been removed were analyzed for lignin content, using TAPPI Standard Method T 222 (4). The stalks contained only 6.2% lignin. Depithed fiber bundles from these stalks contained 5.0% lignin, not significantly different from that of the whole stalks. In contrast, southern pine contains about 27% lignin, known to be the principal cementing material between wood fibers. These results show that lignin is not the major bonding material between fibers in the vascular fiber bundles.

Consultation with experts in the Botany Department at the University indicated that the principal bonding agent in the waterhyacinth stalk is pectin rather than lignin.

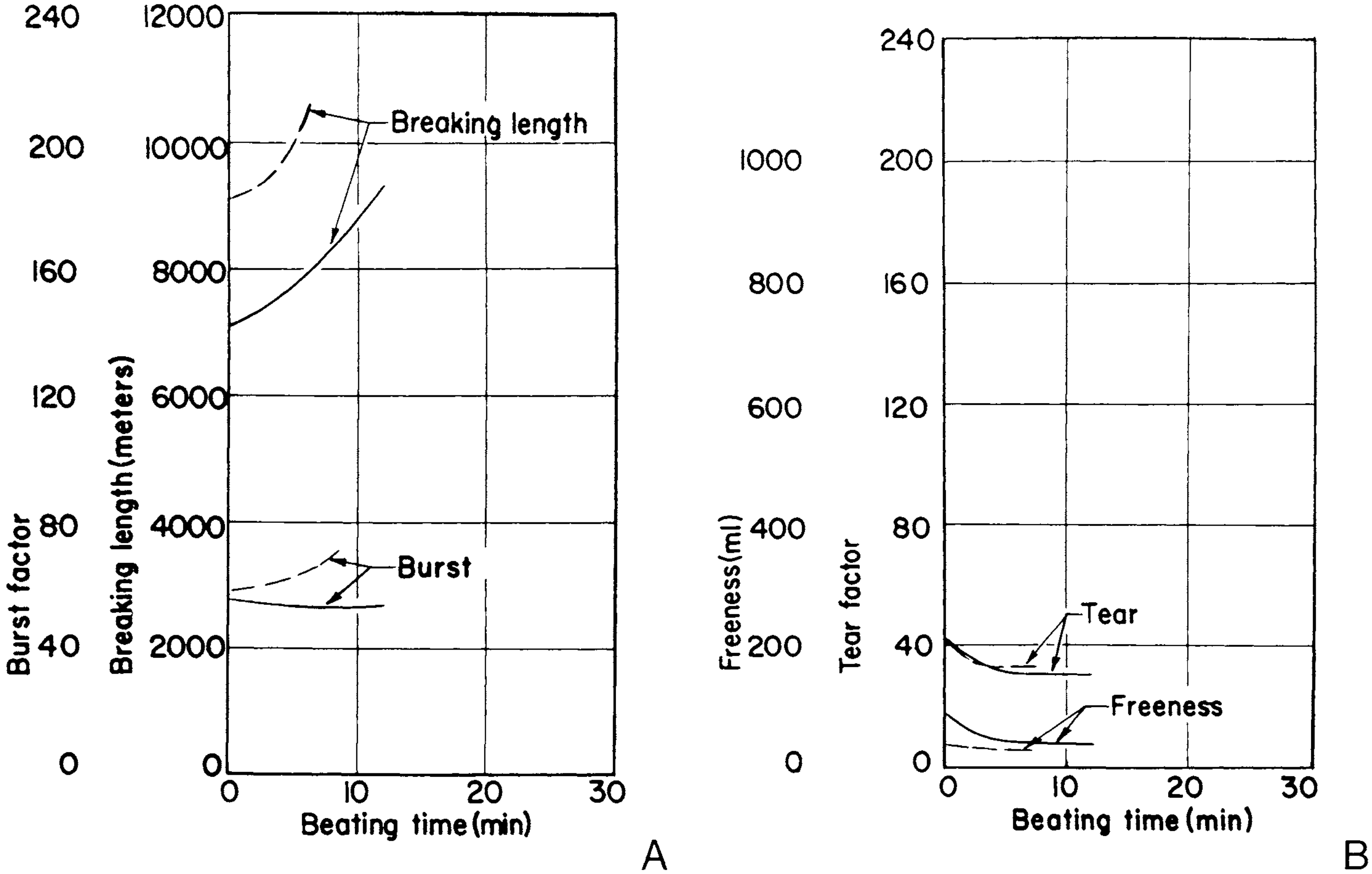

Figure 3. Physical characteristics of alkaline waterhyacinth pulps. ——— sodium hydroxide pulp No. 4362; — — — — — kraft pulp No. 4386. A. Burst factor and breaking length vs. beating time. B. Tear factor and freeness vs. beating time.

Pectin is a hemicellulose, differing in composition from the hemicelluloses in wood and bagasse in that pectic acid is contained in the hemicellulose chain. The hemicelluloses in wood and bagasse are valuable components in paper pulp since they add to tensile and bursting strength of the pulp. The writers know of no chemical agent which will dissolve pectin without also dissolving the other valuable hemicelluloses. It is suspected that the very low freeness values of waterhyacinth pulp fibers may be due to the chemical composition and quantity of hemicelluloses, some of which act as the bonding material between fibers. Only thin film chromatographic equipment, unavailable at the laboratory, can quantitively determine the amount of hemicelluloses in the vascular fiber bundles and the pulps produced from them.

Physical Properties of Pulps: Only a few of the pulps listed in Tables 1 through 4 were converted into handsheets and tested for physical strength. Pulps obtained at yields higher than 75% were undercooked and would not break up into individual fibers in the beater without severe cutting of fibers, resulting in handsheets of low strength values. Only those pulps which reduced easily into individual fibers at the highest possible yields were used for physical testing.

Strength values of the pulps tested were erratic, particularly in breaking length (tensile strength) and bursting strength, making it difficult to fit the data points to a smooth curve of strength vs. beating time. These erratic strength values were probably caused by the low drainage rates as handsheets were formed on the sheet mold. Drainage times of 5 to 10 min were required for sheet formation, as compared to 30 sec or less for wood or bagasse pulps. During these long time periods the longer fibers settled in high concentration on the forming wire, while the fines remained in suspension and were deposited on the top of the sheet. The resultant handsheets were non-uniform in texture, as compared to the uniform distribution of long fibers and fines in sheets made from commercial pulp with high drainage rates.

Another cause of erratic strength values was the tendency of the waterhyacinth sheets to shrink on drying, to a much greater extent than wood pulp sheets. In many cases the dried sheets were wrinkled, making it difficult to cut test specimens to exact dimensions, particularly the breaking length strips.

All waterhyacinth pulps had the unusual charateristic of becoming quite dark upon drying. Sulfite and sulfite-bisulfite handsheets were light in color when placed in the drying rings but the dried sheets were greenish gray. At the outer edge of each sheet, where a rubber gasket prevented contact with air, color was considerably lighter. Pulps cooked by the highly alkaline process exhibited this darkening upon drying to a greater degree than those cooked with neutral or slightly acid chemicals. In all cases sheets were too dark for accurate evaluation of brightness on the G.E. brightness tester.

Typical physical characteristics of paper handsheets made from waterhyacinth pulps cooked by the four chemical processes are shown in Figures 2A and 2B, and 3A and 3B. Figures 2A and 3A show that breaking length is highest for the kraft pulp, followed, in decreasing order, by sodium hydroxide pulp, sodium sulfite pulp made from stalks alone, sulfite pulp made from the whole plant, and the sulfite-bisulfite pulp. The breaking length curve for the sulfite-bisulfite pulp is undoubtedly in error, due to the very low value at 12 min beating time. The same Figures 2A and 3A show small differences in bursting strength for the five pulps, but those produced by the highly alkaline processes are slightly higher than those cooked by the neutral and slightly alkaline liquors.

The higher breaking length and bursting strengths of the alkaline pulps is more than offset by the loss in pulp yield to attain these strengths. The kraft pulp yield was only 44.5%, with 48.6% for the sodium hydroxide pulp, in contrast to a yield range of 65 to 75% for the neutral and slightly acid pulps. From considerations of both yield and strength, the sodium sulfite process appears best suited to waterhyacinth pulping.

Comparison of the curves in Figures 2B and 3B shows that all four processes produce pulps of very low tear strength and freeness. All values are so low that any comparison of processes would have little significance.

Figures 1A and 1B show the strength characteristics and freeness values for 100% pine kraft pulp and for mixtures of pine kraft and sodium sulfite pulp made from waterhyacinth stalks. In Figure 1A, breaking lengths of the mixture containing 35% waterhyacinth pulp are extremely high, followed closely by the mixture containing 50% waterhyacinth. Both of these breaking length curves are much higher than the curve for 100% pine kraft pulp. Figure 1A also shows that the mixtures of waterhyacinth pulp and pine kraft are superior in bursting strength to 100% pine kraft. In fact, pine kraft pulp alone would have to be beaten for 60 min to attain approximately the same breaking length and burst factor as the 35% waterhyacinth mixture beaten only 15 min.

Figure 1B shows that the mixture containing 35% waterhyacinth pulp, while superior in tear strength to the 50% mixture, is very much lower in tear than the 100% pine pulp. The tearing strength of these mixtures would make their use for liner board grades unacceptable commercially but would be acceptable for book or bond grades of paper. However, inspection of the freeness curves for the mixtures and comparing them to the freeness curve for 100% pine shows that drainage rates of the mixtures are so low that it would be impractical to make any grade of paper from them on modern high speed paper machines.

Qualitive bleaching tests to eliminate dark color of the dried pulps indicated that mild peroxide treatment of the pulp might eliminate the discoloration. However, since the very low freeness values of all waterhyacinth pulps eliminated them for commercial papermaking use, no quantitive bleaching studies were made.

Even though this research has proved that commercially acceptable paper pulps cannot be made from waterhyacinths, publication of the procedures and the results obtained will, it is hoped, prevent others from undertaking an expensive research program to develop the use of waterhyacinth plants as a raw material for the paper industry.

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