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PAPERMAKING QUALITY OF CORNSTALKS

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ABSTRACT

Study of the papermaking quality of cornstalks was made at the National Bureau of Standards to find the practical possibilities of utilizing this form of waste farm product as a raw material for paper. Special mechanical preparation of the stalks was found essential for successful pulping because of certain structural peculiarities of the type of plant stem. The best results were obtained by using only the outside shell or cortex, which had been separated from the remainder and shredded by mechanical processes.

The cortex was pulped without difficulty by both the kraft-sulphate and the caustic-soda processes. The use of unbleached pulps in the manufacture of brown wrappings was investigated, but the papers did not compare favorably with wood-fiber wrapping papers. A bleached pulp suitable for use in medium grades of white writing papers and greaseproof specialties was made by the caustic-soda process. Papers made from this pulp had fair strength and satisfactory color, formation, and cleanliness. However, higher costs due to low yields of pulp based on the amount of cornstalks used, place them at a disadvantage with wood as a raw material at present.

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I. INTRODUCTION

The utilization of cornstalks for paper has received much publicity, mainly because of the relatively large supply of readily available fibrous material for which the farmer has no profitable use. For many years cornstalks have been proposed as a source of cellulose, and particularly cellulose pulp for paper. However, although many investigators [1] have experimented with cornstalks and numerous patents [2] have been granted for methods of making paper pulp from them, no successful commercial developments have resulted. Despite the numerous experiments recorded in the literature, the published results were somewhat lacking in detail. Published information did not indicate clearly the most satisfactory pulping methods or the quality of pulp that could be produced from the material. Therefore, in order to determine definitely the papermaking quality of corn-

[1] West, Papermaking Materials, p. 224, Lockwood Trade J. Co. (1928).
[2] Rossman, *Cornstalks in Papermaking*, Paper Trade J. 91, no. 23, 51 (1930).

stalks, it was necessary to make a thorough investigation of the pulping of this material by the processes adapted to crop plants. Some preliminary small-scale pulping experiments made in the branch laboratory of the National Bureau of Standards at Ames, Iowa, in cooperation with Iowa State College, indicated that the stalks could be pulped in the conventional type of equipment.[3] These experiments were followed by an extensive investigation at the Bureau with laboratory-scale and semicommercial-scale equipment, using stalks shipped from Ames.

The semicommercial-scale equipment consisted of a rag duster; rag cutter; rotary boiler; 50-pound, copper-lined, wood-tub beater with manganese-bronze bars and plate and equipped with one washing cylinder; jordan refiner, 4-plate screen; and 29-inch Fourdrinier papermaking machine with a 33-foot wire, two presses, nine 15-inch dryers, a 7-roll machine stack, and a reel. Detailed descriptions of this equipment have been given in previous articles.[4] [5]

II. STRUCTURAL CHARACTERISTICS OF CORNSTALKS

Certain structural characteristics of cornstalks present serious difficulties in reducing them to a satisfactory paper pulp. The most serious obstacle lies in the different character of various parts of the stem which consists essentially of two distinct portions, the outside shell or cortex, and the soft, bulky pith inside. The cortex, which is very much harder at the joints or nodes than in the portion between the nodes, contains a high percentage of fibers of papermaking quality; while the spongy pith consists principally of thin-walled, oblong cells known to be of little value for paper. The fibers comprising the different parts of the stalk differ greatly as to length, and the longest do not compare favorably with the more commonly used wood fibers. This is shown by the comparison in table 1. Detailed information on the physical structure of cornstalks is contained in a previous article by Lofton.[6]

TABLE 1.—*Comparison of fiber lengths*

	Cornstalks			Woods			
	Cortex	Nodes	Leaf sheath	Spruce	Hemlock	Yellow pine	Poplar
Fiber length (millimeters)	1.65	0.62	1.17	2.69	3.62	3.17	1.46

The concentration of chemicals necessary to disintegrate the different parts of the stalk differs very much. The cortex requires a much stronger cooking liquor than the pith, and unless thoroughly broken by preliminary mechanical treatment, the nodes require much more drastic cooking than the remainder of the cortex. Therefore, if the entire stalk is cooked for the purpose of producing fibers, the concentration of chemicals necessary to pulp the cortex practically destroys

[3] The authors gratefully acknowledge the assistance of B. Wingfield, E. R. Whittemore, and C. B. Overman in making the preliminary experiments and preparing the cornstalks for the work done at the Bureau.
[4] Tech. Pap. BS 21, 323 (1925) T340.
[5] Paper Trade J. 89, no. 19, 60 (Nov. 7, 1929).
[6] Paper Trade J. 91, no. 5, 39 (July 31, 1930).

the thin-walled pith cells, and the concentration required to soften uncrushed nodes greatly overcooks the remainder of the stem. The difficulties presented by the structural characteristics of the stalks and by the excessive amounts of dirt always present in field-gathered cornstalks made it essential to study the efficiency of different mechanical treatments before cooking, as well as different cooking conditions.

III. EXPERIMENTS IN PULP AND PAPER MANUFACTURE

1. MECHANICAL PREPARATION OF STALKS

Three different kinds of mechanical treatment were used to prepare stalks for cooking with chemicals in the rotary digester. Pulping tests were made on the entire stalks cut into short lengths and dusted; on the entire stalks shredded; and on the outside shell or cortex only, well shredded to break up the hard nodes.

Cut stalks were prepared by first agitating them in a rotary duster, covered with a no. 5 wire screen, to remove the loose dirt; then reducing them to approximately 1-inch lengths in a rag cutter. The loss in dusting was 5 percent, and since the moisture content of the baled stalks was 10 percent, the yield of cut stalks was approximately 85 percent on a dry basis.

The shredded stalks used were prepared at Ames, on the conventional farm-type shredder, before shipment to the Bureau. No data were obtained on the loss in shredding, but, inasmuch as it is known that dirt and other fine material are removed in the process, the dry basis yield of shredded stalks was estimated to be the same as for the cut and dusted stalks.

The outside shell or cortex was processed in the branch laboratory at Ames, by a method developed there. The process consists essentially in shredding the stalks and washing them thoroughly; breaking the pith loose in an attrition mill; and separating the cortex from the pith and extremely short-fibered, fine material by wet screening and water separation. The yield of dry cortex was 43 percent based on the weight of baled stalks containing dirt and 10 percent of water. The cortex was in much better condition for pulping than whole stalks in any form, because it consisted principally of fibers suitable for paper, and much of the dirt had been washed out in the wet separation process.

2. PULP AND PAPERMAKING

In this study of cornstalks, the lime, caustic soda, and sulphate or kraft pulping processes, three well-known operations adapted to the pulping of crop plant materials, were investigated. A series of laboratory-scale experiments made in the branch station at Ames were followed by 8 laboratory-scale and 15 semicommercial cooks (pulping experiments), and 16 paper-machine runs at the National Bureau of Standards. Data on the semicommercial-scale pulping experiments and the accompanying paper-machine runs are given in table 2.

IV. DISCUSSION OF RESULTS

1. EFFECT OF MECHANICAL PREPARATION OF STALKS

The most satisfactory results were obtained by using the cortex of the stalks. The pulps made from this were not only stronger but were cleaner and worked much better on the paper-machine. Those from the entire stalks were very dirty, even after excessive washing, and the fibers tended to stick to the paper machine wire. As no mineral filler was used in any of the papers, their comparative cleanliness is indicated by the ash contents; low ash content is indicative of low dirt content. While the cortex constitutes only 43 percent of the gross weight of the entire stalks, the average pulp yields, using cortex, were only approximately 5 percent less than the yields from the entire stalks in either the cut or shredded form. Inasmuch as twice as much digester capacity and chemicals are required to pulp the cut or shredded stalks constituting 85 percent of the original stalks, as for the cortex constituting 43 percent, the economy of using the cortex alone is apparent.

TABLE 2.—*Cornstalk-paper data*

ENTIRE STALK IN APPROXIMATE ONE-INCH LENGTHS

Experiment identification—machine run numbers	Pulp					Paper												Quality of experimental papers
	Cooking chemicals		Kind of cook	Bleach used	Yield of pulp [1]	Thickness	Weight 25×40:500	Degree of sizing [2] (dry indicator)	Ash	Bursting strength	Ratio of bursting strength to weight (25×40:500)	Folding endurance [5] (double folds)		Tensile breaking strength [6]		Tearing strength		
	Chemicals	Amounts										Machine	Cross	Machine	Cross	Machine	Cross	
		Percent		*Percent*	*Per cent*	*Inch*	*Pounds*	*Seconds*	*Per cent*	*Points* [4]	*Percent*			*Kilograms*	*Kilograms*	*Grams*	*Grams*	
1065	Lime Na_2CO_3	25 6	Lime															Paper worthless, not tested.
1066	NaOH	15	Soda		26.4	0.0043	56.6	56	3.2	23	40			6.6	4.0	51	49	Brown wrapping, poor strength, dirty.
1067	Na_2S NaOH	5 7.5	Kraft		32.8	.0042	56.6	46	4.0	25	44			6.2	4.1	43	42	
1068	NaOH	15	Soda		35.7	.0042	57.4	40	2.7	26	45			6.6	4.3	53	50	
ENTIRE STALKS SHREDDED																		
1074	Na_2S NaOH	3 6	Kraft		36.6	0.0038	51.6	38	4.9	20	39			5.7	3.8	34	33	Brown wrapping, poor strength, dirty.
1075	Na_2S NaOH	3 6	do		31.4	.0040	54.2	47	4.3	29	54	42	34	6.7	4.6	42	39	
1080	NaOH	20	Soda		27.2	.0030	40.5	7	4.3	22	54	190	65	5.8	3.2	28	25	Brown wrapping lightweight, fair strength, fairly clean.

Footnotes at end of table.

TABLE 2.—*Cornstalk-paper data*—Continued

CORTEX

Experiment identification—machine run numbers	Pulp: Cooking chemicals: Chemicals	Pulp: Cooking chemicals: Amounts	Pulp: Kind of cook	Pulp: Bleach used	Pulp: Yield of pulp [1]	Paper: Thickness	Paper: Weight 25×40:500	Paper: Degree of sizing [2] (dry indicator)	Paper: Ash	Paper: Bursting strength	Paper: Ratio of bursting strength to weight (25×40:500)	Folding endurance [5] (double folds): Machine	Folding endurance [5] (double folds): Cross	Tensile breaking strength [6]: Machine	Tensile breaking strength [6]: Cross	Tearing strength: Machine	Tearing strength: Cross	Quality of experimental papers
		Percent		*Percent*	*Percent*	*Inch*	*Pounds*	*Seconds*	*Percent*	*Points* [4]	*Percent*			*Kilograms*	*Kilograms*	*Grams*	*Grams*	
1069	NaOH	15	Soda	--------	25.0	0.0038	54.8	38	1.5	23	42	--------	--------	6.7	4.4	39	37	Brown wrapping, poor strength, fairly clean.
1070	NaOH	10	do	--------	28.3	.0038	54.4	40	1.6	23	42	53	49	6.4	4.2	35	34	Brown wrapping, poor strength, fairly clean.
1071	Na_2S NaOH	5 7.5	Kraft	--------	24.1	.0038	55.4	46	1.6	25	45	86	66	7.1	4.6	37	37	Brown wrapping, poor strength, fairly clean.
1072	Na_2S NaOH	3 6	do	--------	27.1	.0039	55.3	46	2.0	22	40	51	49	6.8	4.6	38	39	Brown wrapping, poor strength, fairly clean.
1073	Na_2S NaOH	2 4	do	--------	28.8	.0039	57.0	43	2.0	23	40	12	13	6.4	4.1	35	33	Brown wrapping, poor strength, fairly clean.
1079	Na_2S NaOH	3 6	do	--------	23.7	.0038	57.2	37	1.6	29	51	114	72	7.2	4.6	44	40	Brown wrapping, fair strength, clean.
1076	NaOH	20	Soda	10	28.1	.0036	55.4	37	1.7	31	56	65	72	8.4	5.1	39	37	White writing, fair quality, clean.
1077	NaOH	25	do	9	19.1	.0036	56.3	33	1.7	30	53	47	48	8.4	4.8	42	41	Brown wrapping, fair strength, good color, clean.
1078	Made from waste paper [3]					.0026	39.1	14	1.9	21	54	105	60	4.9	3.0	21	20	White greaseproof type, satisfactory.

[1] Yield values are based on weight of baled cornstalks as received from Ames, Iowa, with a moisture content of 10 percent.
[2] All papers were beater sized with rosin sizing.
[3] The material used for this run consisted of waste paper from machine runs 1076 and 1077.
[4] Bursting pressure in pounds per square inch, through a circular orifice 1.2 inch in diameter.
[5] For test specimen 15 mm wide and 90 mm between jaws.
[6] For test specimen 15 mm wide and 100 mm between jaws.

2. BROWN WRAPPING PAPERS

The brown wrapping paper having the most satisfactory strength and cleanliness was made in machine run no. 1079. This paper, however, was much inferior to a commercial no. 2 kraft wrapping, which would be a competitive paper. The superiority of the kraft may be seen by comparing the properties of the cornstalk paper with the United States Government Printing Office specification requirements for no. 2 kraft as shown in table 3.

TABLE 3.—*Comparison of cornstalk wrapping paper with no. 2 kraft requirements*

Paper stock	Ratio of bursting strength to weight	Folding endurance average
	Percent	*Double folds*
Spec. GPO no. 2 kraft	70	500
Cornstalk paper, MR1079	51	93

The yield, 23.7 percent, could doubtless be improved slightly by using a finer screen for dusting the cortex; probably 25 percent can be obtained. Using that figure, 4 tons of stalks would be required for sufficient cortex to make 1 ton of pulp. At an estimated [7] cost of $7.15 per ton for baled cornstalks at the mill, and $1 per ton for separating the cortex, the cost of stalks would be $32.60 per ton of pulp, which is approximately four times the cost of the pine wood required for a ton of no. 2 kraft. In addition, the manufacturing costs would be much higher for cornstalks. Cornstalk material is so light and bulky that it is impossible to charge a satisfactory amount into a digester of ordinary capacity, as compared with wood. This would necessitate greater expense for digester equipment, and result in greater cost of chemicals, because the larger volume of liquor necessary to cover the bulky digester charges would mean liquor dilutions that would greatly increase the cost of recovery of chemicals. Also the handling costs would be much greater for the light bulky cornstalk material.

From a consideration of the poor quality of the paper and its relatively high cost, the utilization of cornstalks for ordinary wrapping papers does not appear to have commercial possibilities. Even if the cost of wood were to be increased to four times current prices, cornstalks could not compete successfully with wood for use as a raw material for this class of paper.

3. WHITE PAPERS

Bleached writing paper of fair quality was made from cortex that was thoroughly dusted before cooking. The best paper of this type was made in machine run 1077. This paper had fair strength together with good color, formation, and cleanliness, and it was considered suitable for many of the purposes for which sulphite writing papers are commonly used. That the strength requirements of the United States Government Printing Office specification for sulphite writing paper of comparable weight were exceeded by this paper is shown in table 4.

[7] Sweeney and Arnold, Bul. 98, Iowa State College.

TABLE 4.—*Comparison of cornstalk writing paper with sulphite writing paper requirements*

	Weight 25×40: 500	Bursting strength	Folding endurance
	Pounds	*Points*	*Double folds*
Sulphite writing, GPO specification	54	25	30
Cornstalk paper, MR1077	56	30	47

Chemical analyses were made to find the purity of the writing papers. Results of alpha cellulose,[8] copper number,[9] and resin [10] determinations are contained in table 5.

TABLE 5.—*Chemical tests* [1] *of cornstalk writing papers*

Paper	Alpha cellulose	Copper number	Resin
	Percent		*Percent*
MR1076	72.66	1.31	2.06
MR1077	77.51	1.07	2.12

[1] These tests were made by the methods of the Technical Association of the Pulp and Paper Industry.

The alpha-cellulose content of the papers was somewhat low although that of MR1077 compared quite favorably with commercial sulphite papers and the copper number was much lower than is commonly found in sulphite papers.

A greaseproof type of paper was also made from the bleached pulp in machine run 1078, using waste paper from machine runs 1076 and 1077. In the commercial manufacture of greaseproof papers the parchment-like properties are obtained by drastic mechanical treatment in the beater and that procedure was followed in the preparation of stock for this paper. The paper was somewhat comparable in character to commercial papers commonly used for wrapping butter, lard, and similar products, and it was very satisfactory as regards strength, formation, color, and cleanliness. No attempt was made to obtain a high degree of grease resistance; however, this could doubtless be accomplished by the special processes employed in the manufacture of commercial greaseproof papers.

According to the data obtained, 5.2 tons of cornstalk would be required for sufficient cortex to make 1 ton of pulp for white papers. Allowing $7.15 per ton of cornstalks at the mill, and $1 per ton of stalks additional for separation of cortex, the cost of stalks would be $42.38 per ton of pulp. This is approximately 60 percent higher than the cost of the spruce wood required for a ton of sulphite (2 cords), and to this cost differential must be added the higher conversion costs caused by smaller digester charges, higher handling costs, and greater consumption of chemicals.

[8] The alpha-cellulose content of cellulosic material is that part which is insoluble in a sodium hydroxide solution of mercerizing strength (17.5 percent NaOH) under certain specified conditions, and is regarded as a measure of the amount of unmodified cellulose. High alpha cellulose is indicative of good fiber quality.

[9] The copper number indicates the amount of copper reduced from alkaline copper solution by the modified cellulose present. High copper number is indicative of the presence of harmful impurities.

[10] The resin content of paper indicates the amount of rosin sizing, plus the natural resins present.

V. SUMMARY AND CONCLUSIONS

The low strength of cornstalk fibers, together with the comparatively high raw-material and manufacturing costs, appears to preclude at present commercial success in utilizing domestic cornstalks for ordinary wrapping papers and similar unbleached papers.

White pulp of satisfactory quality for medium grades of writing papers, and bleached wrapping specialties such as butter and lard wrappers was produced. However, the commercial manufacture of this type of pulp does not appear feasible at the present time on account of the relatively high costs of raw materials and conversion. Before the process can be of commercial interest under present conditions, it will be necessary to find profitable uses for the pith and fine fibrous material which are left after separating the cortex. If these or other byproducts [11] could be made to pay the cost of separating the cortex and one-half the raw material costs, reducing the cost of the cortex to about $18 per ton of pulp, it is possible that the cortex could be used profitably for bleached pulp.

Washington, November 19, 1934.

[11] Materials obtained experimentally from cornstalks that may ultimately be of commercial interest include xylose, alcohols, adhesives, lignin, maizolith, furfural, plastics, and low-density thermal and sound-insulating material from the pith and fines.

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