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SUITABILITY OF SWEETPOTATO STARCH FOR THE BEATER SIZING OF PAPER

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ABSTRACT

In order to obtain information on the value of starch made from cull sweetpotatoes, a waste farm product, as beater sizing for paper, 26 paper-machine runs were made in the Bureau's semicommercial mill. In this work, sweetpotato starch was used in comparison with high-grade commercial starches made from corn and cassava. The relative merits of the different starches used were determined by comparing the results obtained with respect to retention of starch, retention of mineral filler, and properties of the finished papers. In general, the use of beater starch improved the retention of mineral filler and increased the bursting strength of the papers. Starch aided materially in filling the pores of the sulphite-soda papers, as indicated by decreased air permeability. No apparent effects on the degree of sizing were noted, and the opacity was generally slightly decreased where starch was used. The papers containing sweetpotato starch were not inferior in any respect to those containing corn and cassava starches, and superior results with respect to retention of mineral filler, and "closing of the sheet", were obtained with the sweetpotato starch. Apparently the starch made from the waste farm product is excellent for beater sizing, being at least as good as the corn and cassava starches commonly used for this purpose.

CONTENTS

I. INTRODUCTION

A method of producing high-grade starch from cull sweetpotatoes, a waste farm product, has been developed by the Carbohydrate Division of the Bureau of Chemistry and Soils of the United States Department of Agriculture.[1] In order to assist in appraising the potential uses of this starch, its comparative quality as beater sizing for paper was studied at the National Bureau of Standards. Starch is widely used as beater sizing in book papers and other printing papers, mainly for its adhesive property which helps bind the fibers together, increases the bursting strength, and improves the retention of mineral filler. Starch improves the printing quality of some papers by closing the sheet without excessive mechanical beating, and by laying surface fuzz. Corn and cassava starches are now used almost exclusively in this country for the purpose; hence the commercial use of sweetpotato starch in this field depends on its utility relative to those starches.

[1] Ind. Eng. Chem. 25, 919 (1933).

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The chemical and physical properties of the three different kinds of starches had been shown by Thurber;[2] however, no information was available on the value of sweetpotato starch for use in the manufacture of paper. Such information was obtained by making, on the semicommercial equipment at the Bureau, a series of papers using sweetpotato starch in comparison with representative commercial starches made from corn and cassava.

The papermaking equipment used in the study consisted of a 50-pound copper-lined wood-tub beater with manganese-bronze bars and plate; a Jordan refiner; a 4-plate screen; and a 29-inch fourdrinier papermaking machine with a wire 33 feet in length, 2 presses, nine 15-inch dryers, a 7-roll machine-calender stack, and a reel. Detailed descriptions of this equipment have been given in previous articles.[3] [4]

II. PREPARATION AND USE OF STARCHES

Starch is useful as a sizing in paper only when added as a gelatinous, colloidal solution, with adhesive strength. Natural, or unmodified, starch is not affected by cold water, hence it must be gelatinized before adding to the fiber furnish, if it is to be of value. When a water suspension of starch is heated, the starch granules absorb water, and swell to many times their original size, to form a gelatinous paste, which is added to the beater furnish. The swelling begins at 60 to 83° C and the paste thickens with increased temperature until a maximum viscosity is reached, after which the viscosity rapidly decreases if the temperature is maintained. The temperatures at which gelatinization begins and the maximum viscosity is reached vary according to the origin of the starch; also, different kinds of starch vary greatly with respect to the viscosity of pastes made from them. Data on the gelatinization temperatures and viscosities of unmodified starches made from corn, cassava, and sweetpotatoes are given in an article by Thurber.[5]

Some of the starches employed for beater sizing are used in a modified form. The starch may be modified by acid-hydrolysis or by oxidation, and the principal effect of either method is a reduction in the viscosity of the paste which the starch will make when heated with water. Starch is also marketed in a gelatinized form for use by adding to the beater without swelling. The preparation of gelatinized starch consists essentially in swelling the starch in water, drying the paste, and grinding.

Information contained in the literature and obtained from starch manufacturers indicated that the practice with respect to the preparation of starch pastes for beater sizing varies greatly. Hence, it was necessary to determine, by trial, the best method of preparing the sweetpotato starch for use in the beater. Four different methods were used in preparing the pastes used in the first series of papers. For machine run 1052, (see table 1) a 1:25 suspension of starch in water was heated to 70° C, cooled, and added to the beater at the start of the beating cycle; for machine run 1057, the temperature of the starch suspension was raised to 68° C and the solution added to the beater ½ hour before the end of the beating cycle, after the clay,

[2] Ind. Eng. Chem. **25**, 565 (1933).
[3] Tech. Pap. BS **21**, 323 (1925) T340.
[4] Paper Trade J. [89] **19**, 60 (Nov. 7, 1929).
[5] See footnote 2.

rosin sizing, and alum had been added; the same procedure was followed in machine run 1058 as in the preceding, except that the temperature of the starch was raised to 80° C; and the conditions were the same for machine run 1060, except that the temperature of the starch suspension was raised to only 61° C.

These preliminary runs indicated that the best results were obtained with sweetpotato starch when the gelatinization was stopped before the maximum viscosity was reached, so that further swelling might take place in the paper when in contact with the hot driers. The preparation for subsequent runs consisted in heating a suspension of 1 part of starch in 25 parts of water to 68° C, with constant agitation, then cooling the paste to prevent further swelling, and adding it to the beater furnish. The starch undergoes no further swelling after being cooled to the temperature of the beater furnish, and is unaffected under normal conditions by the alum used to precipitate the rosin sizing; therefore, the time at which it was added to the beater was apparently not important, provided thorough mixing with the fibers was accomplished. In the preliminary experiments with sweetpotato starch, the time of adding had no apparent effect, and this starch was added ½ hour before the completion of the beating cycle n subsequent runs.

The commercial starches were prepared and used in accordance with the manufacturers' directions, on the assumption that each manufacturer has determined the method that gives the best results with his particular product.[6]

III. MANUFACTURE OF EXPERIMENTAL PAPERS

It was not a purpose of the investigation to determine the effects of different amounts of starch in paper. Hence, in order to have comparable data on the results obtained with different starches, the same amount was used in each experiment. The amount used, 2 percent, was selected because it represented common commercial practice.

The papers made were all book papers. The following fiber combinations were used: 50 percent of sulphite, 50 percent of soda;[7] 50 percent of rag, 50 percent of sulphite; and all-rag fiber made from 60 percent of new rags. Papers of each type were made without starch, with sweetpotato starch, with the commercial starches, and with and without clay filler. All papers of each type were made the same, except with respect to the use of starch and filler, as indicated by the data in table 1. Different papers of the same type containing the same kind of starch were made the same, except with respect to the preparation of or time of adding the starch paste.

[6] Manufacturers' directions were not followed in preparing the starches for machine runs 1062 and 1061. These were repeat runs for 1051 and 1053, respectively, and methods of preparation were altered in an effort to obtain better results.

[7] Sulphite is a term used to designate wood fibers prepared by the acid-sulphite process; soda is a term used to designate wood fibers prepared by the alkaline-soda process; and rag fibers are obtained from rags, principally cotton.

TABLE 1.—*Data on starch-sized papers*

Machine run number	Starch sizing [2]				Clay filler [3]			Ash [4]	Weight 24×40, 500	Thickness	Air permeability [5]	Opacity	Water resistance (dry indicator method)	Bursting strength	Tensile properties [7]				Tearing strength	
	Kind of starch [1]	Amount used	Amount in paper	Retention	Amount in beater	Amount in paper	Retention								Breaking load		Elongation at rupture		Machine direction	Cross direction
															Machine direction	Cross direction	Machine direction	Cross direction		
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Inch*	cm³/sec/m²/g/cm²	*Percent*	*Seconds*	*Points* [6]	kg	kg	*Percent*	*Percent*	*Grams*	*Grams*
SULPHITE-SODA PAPERS																				
1048	Blank	0						0.49	56.1	0.0040	72.8	88	42	21	6.3	4.0	1.7	4.9	41	40
1049	do	0			14.8	11.9	74.1	10.84	57.0	.0038	74.5	93	39	16	4.8	2.8	1.5	4.0	40	41
1050	Corn A	2	1.16	55	14.8	11.0	70.9	10.02	56.6	.0038	58.1	92	35	18	5.6	3.1	1.6	4.4	35	37
1051	Corn B	2	.28	13	14.5	8.8	58.0	8.18	53.8	.0037	62.4	91	44	19	5.4	3.3	1.5	4.2	33	38
1062	do	2	.43	19	14.2	7.3	53.7	7.82	57.2	.0038	40.4	89	41	20	5.9	3.5	1.6	5.0	37	38
1059	Corn D	2	1.41	66	14.5	12.4	79.4	11.30	54.2	.0038	37.5	90	44	18	5.2	3.0	1.7	4.0	35	34
1052	Sweetpotato	2	.63	30	15.1	11.4	72.0	10.39	56.7	.0038	44.5	92	49	19	5.6	3.4	1.6	4.6	33	33
1057	do	2	1.23	58	14.7	12.6	83.5	11.47	54.5	.0037	39.9	90	41	18	5.5	2.8	1.7	4.6	33	32
1058	do	2	.71	33	14.6	12.4	82.4	11.32	55.3	.0037	43.2	92	40	19	5.3	3.2	1.7	4.6	33	32
1060	do	2	1.31	62	14.4	12.3	78.9	11.15	53.6	.0035	30.0	90	39	16	4.9	2.7	1.7	4.6	35	35
1053	Cassava	2	.46	22	15.0	12.3	79.0	11.20	53.9	.0036	47.6	90	39	16	4.9	2.7	1.7	4.2	35	32
1061	do	2	.54	26	14.5	12.3	78.3	11.17	54.1	.0035	40.1	90	42	18	5.1	2.8	1.7	4.6	35	35
RAG-SULPHITE PAPERS																				
1063	Blank	0						0.33	53.3	0.0034	4.6	82	31	25	6.2	3.5	2.5	6.9	49	49
1064	do	0			14.4	12.6	80.9	11.26	55.2	.0035	8.2	89	10	17	4.7	2.6	2.2	6.1	48	47
1086	Corn A	2	1.23	58	16.0	15.0	88.5	13.50	56.6	.0035	9.5	91	11	21	5.1	3.4	2.0	5.8	48	47
1087	Corn B	2	.62	29	14.2	11.2	72.9	10.10	57.3	.0037	10.5	90	18	22	5.5	3.7	2.0	6.0	50	51
1088	Cassava	2	.26	12	14.2	13.2	87.1	11.80	56.5	.0036	13.4	91	15	19	5.1	3.3	2.1	6.1	51	53
1089	Sweetpotato	2	.88	41	14.2	13.4	88.1	11.94	54.1	.0033	11.7	91	14	21	5.4	3.7	2.2	6.3	46	47

1090	Blank	0						0.34	56.2	0.0037	15.7	87	9	26	6.4	4.2	2.7	5.9	86	90
1091	Corn A	2	1.41	66				.32	56.1	.0038	18.7	86	18	30	6.7	4.3	2.6	6.3	83	86
1092	Corn B	2	.96	45				.30	55.3	.0035	16.5	83	16	29	6.7	4.8	2.8	6.4	83	87
1093	Cassava	2	.72	34				.36	55.6	.0037	16.8	86	20	31	7.1	4.8	2.6	6.4	85	98
1094	Sweetpotato	2	1.40	66				.34	56.5	.0038	15.0	85	18	34	7.2	5.1	3.0	6.6	83	98
1095	Blank	0			14.0	13.2	87.9	11.78	56.3	.0035	20.2	92	5	17	4.6	2.9	2.0	5.5	80	92
1096	Sweetpotato	2	1.60	75	14.4	13.5	87.8	12.09	55.9	.0035	16.6	91	8	25	5.5	3.7	2.8	6.2	76	80
1097	Corn A	2	1.48	70	14.5	13.5	87.4	12.09	57.5	.0037	16.2	91	7	22	5.2	3.5	2.4	6.4	72	85

[1] Starch B was corn starch modified by oxidation; starch D was a gelatinized corn starch added dry; all other starches were natural or pearl starches.
[2] The starch sizing was in addition to 1½ percent of rosin sizing used in all of the papers.
[3] The percentage of filler in the paper and the retention were determined by the methods used in previous investigations and described in Tech. Pap. BS 301, p. 740 (1925).
[4] Unless otherwise mentioned, the tests of the papers were made by the standard methods of the Technical Association of the Pulp and Paper Industry. Copies of the methods may be obtained from the Association at 122 E. 42nd St., New York, N. Y.
[5] Determined with the Carson permeability tester, BS J. Research 12, 567 (1934) RP681.
[6] Bursting pressure in lb./in.² through a circular orifice 1.2 inches in diameter.
[7] For test specimens 15 mm wide and 100 mm between jaws.

IV. DISCUSSION OF RESULTS OBTAINED WITH STARCH SIZINGS

1. SULPHITE-SODA BOOK PAPERS

It is obvious that in order to obtain benefits from starch and clay filler, substantial quantities must remain in the finished paper. The retention of starch was rather low in the sulphite-soda papers, the average being 38 percent. However, the sweetpotato starch showed up well in comparison with the other kinds, the average retention for that starch being 46 percent as compared to 38 and 24 percent for corn and cassava starches, respectively. In general, the retention of clay filler was improved by the starches, the outstanding exception being corn starch B, a modified starch, which apparently reduced rather than increased the retention of filler. The best retention of filler in this group was obtained with sweetpotato starch in machine run no. 1057. Other properties affected by starch sizing were air permeability, opacity, bursting strength, and tearing strength. Starch aided in closing the sheet, as indicated by reduced air permeability, and helped to lay surface fuzz, both of which aid the printing quality. The data show that the lowest air permeability was obtained with sweetpotato starch. In general, the bursting strength and tensile strength of the sulphite-soda papers were increased somewhat by starch, but some resistance to tear was sacrificed and the presence of starch lowered the opacity.

2. RAG-SULPHITE BOOK PAPERS

Some of the results obtained with starch were quite different for this type of paper than for the sulphite-soda type. The retention of starch was approximately the same as for the sulphite-soda papers, and the effects on the retention of clay filler were also much the same; however, while the effects on the properties of the papers were of the same order as for the sulphite-soda papers, except for air permeability, they were less pronounced. In these papers, starch increased rather than decreased air permeability. The only significant differences between results obtained with the different kinds of starch were relative to starch retention and air permeability. Very unsatisfactory retention of clay filler was again obtained with corn starch B.

3. ALL-RAG BOOK PAPERS

Two series of all-rag papers were made. The first was made without clay filler, since many such papers contain little filler, and the second with approximately 14 percent of filler added.

The retention of starch was much better in the all-rag type of papers than in either of the preceding, the average being 59 percent. The effects of the starch were much the same as for sulphite-soda papers, except that no significant effects on the retention of clay filler or on air permeability were apparent. The bursting strength was increased appreciably and the tearing strength and opacity were decreased. The best starch retention was obtained with sweetpotato starch in machine run no. 1096.

The effects of clay filler on the properties of paper may be seen by comparing data for machine runs 1090 and 1095 of this group, also 1063 and 1064 of the rag-sulphite papers, and 1048 and 1049 of the sulphite-soda papers. In each comparison, the two papers were made the same, except that one contained approximately 14 percent of filler and the other none. In general, clay filler increased the air permeability, improved the opacity, and decreased the strength and water resistance.

4. EFFECTS OF STARCH ON STABILITY OF PAPER

Since the stability of book papers is of importance in its relation to lasting quality, information on the resistance to deterioration of papers containing different kinds of starch was obtained. Sulphite-soda papers from machine runs 1050, 1060, and 1061, containing corn, sweetpotato, and cassava starches, respectively, were subjected to an accelerated-aging test [8] [9] [10] employed by the Bureau for testing stability of papers. The retention of folding endurance after heating was 74, 74, and 68 percent, respectively, for the three papers, indicating no significant differences in the stability of papers sized with the different kinds of starch.

V. SUMMARY AND CONCLUSIONS

The results of the comparative tests described indicate that sweetpotato starch is as satisfactory a beater sizing for paper as the commercial corn and cassava starches commonly used. Papers sized with sweetpotato starch were equal to the best papers sized with the other starches with respect to strength, opacity, and degree of sizing. Superior retention of mineral filler, and closing the sheet, as indicated by the air permeability, were obtained with the sweetpotato starch. A limited number of tests indicated that the papers containing sweetpotato starch were as stable as those containing other starches.

Washington, March 23, 1935.

[8] BS J. Research 7, 466 (1931) RP352.
[9] Paper Trade J. [95] 4, 28 (July 28, 1932).
[10] BS J. Research 11, 727 (1933) RP620.