Sweet Potato Starch as a Sizing Agent in the Textile Industry

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ABSTRACT

An intensive study to determine the possibilities of sweet potato starch as a warp sizing agent in the textile industry has been made in the laboratories of the Engineering Experiment Station of the Alabama Polytechnic Institute in cooperation with the Bureau of Standards and the Bureau of Agricultural Chemistry and Engineering of the Department of Agriculture at Auburn.

Various tests were developed for the evaluation of starches as a sizing agent and sweet potato starch was evaluated by means of these and other tests. As a result of this work it was found that sweet potato starch has the qualities of a good warp sizing agent and in some respects it is superior to a high-grade commercial starch.

Sweet Potato Starch as a Sizing Agent in the Textile Industry

INTRODUCTION

FOR THE past several years there has been much interest in the development of a commercially usable starch from an important product of the South, namely, sweet potatoes. As early as 1930 the United States Department of Agriculture started an investigation of the production of starch from sweet potatoes[1]. Shortly afterwards an intensive study was started in the laboratories of the Engineering Experiment Station of the Alabama Polytechnic Institute, with the United States Bureau of Standards and later the Bureau of Agricultural Chemistry and Engineering of the United States Department of Agriculture at Auburn cooperating, to determine the possibilities of sweet potato starch as a warp sizing agent.

This report is a brief resume of the work and includes methods of testing, descriptions of testing apparatus, and discussions which proved of value in establishing a place for sweet potato starch. Some of these have been reported and published previously[2,3]. These tests and apparatus may prove of value to the textile industry in future control work, especially in working out size formulae and in judging various sizing agents.

EXPLANATION OF THE TERM "WARP SIZING"

One of the main issues encountered in the development of a new product is the question of its commercial feasibility. The textile industry in the United States uses approximately three hundred million pounds of starch a year, of which twenty-five per cent is imported. Thus it was realized that starch made from sweet potatoes must, in order to gain a place on the market, compete with other starches as well as meet the requirements of a good warp sizing agent. With this in mind a comprehensive study of the sizing practice was made and methods of testing and apparatus were developed and used in determining the qualities of sweet potato starch as a warp sizing agent.

In general cotton mill practice it is necessary to reinforce the cotton warp yarns prior to weaving by treating them with a sizing mixture, the principal constituent of which is starch—thus the term "warp sizing". To do this, several hundred yarns are simultaneously drawn from a large spool called "beam" through a sizing machine known as a "slasher". The slasher consists primarily of a steam heated stationary size vat and two or more large horizontal drying

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[1] "Production of Starch from Sweet Potatoes"—Balch and Paine, Ind. and Eng. Chem. **23**, 1205 (1931).
[2] "Experimental Slasher"—Schreiber and Moore, Textile World, July 1939.
[3] "Effects of Sizing, Weaving, and Abrasion on the Physical Properties of Cottn Yarn"—Schreiber, Geib, and Moore, National Bureau of Standards Research Paper No. 623, May, 1937.

cylinders which rotate and are also heated by steam. As the yarns pass from the beam they are immersed in the size vat, pass over the drying cylinders where they are properly dried, and are finally wound as sized yarns on to another beam which is later placed on the loom for weaving. This process is often termed "slashing".

DEVELOPMENT OF SMALL-SCALE SLASHER

In order to facilitate laboratory work and curtail expenses in preparing sized yarns for testing, a small-scale or miniature experimental slasher was developed. It was constructed as simply as possible and yet embodied the essentials of a regular mill slasher.

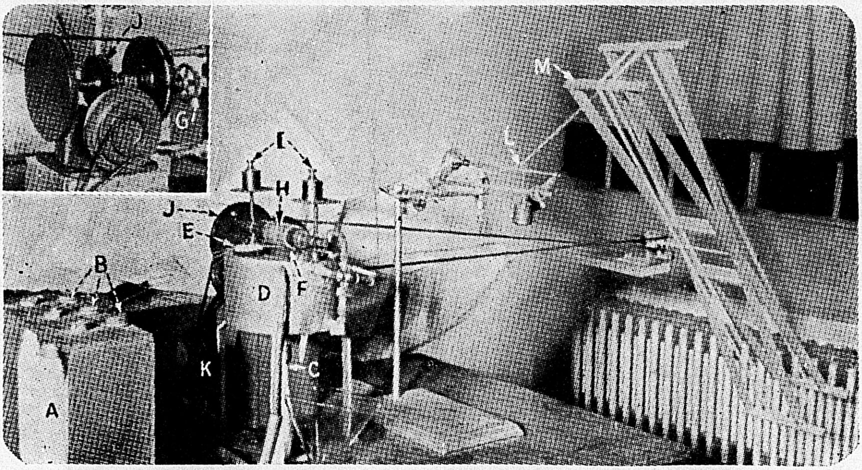

FIGURE 1.—MINIATURE EXPERIMENTAL SLASHER.

Speed-reducing gear is shown in insert. A, bobbin creel; B, yarn-tension disks; C, gas burner to heat steam chest; D, slasher vat and steam chest; E, starch immersion bath (porcelain dish with guide wires extended across the bottom to keep yarn immersed during slashing); F, hollow brass driving roll 1⅝ in. in diameter and 7½ in. long; G, driving roll gear; H, solid brass squeeze roll 1¼ in. in diameter and 7½ in. long covered with woolen blanket; I, weights to control pressure on squeeze roll, lower ends of upright rods extending from the vat and holding the weight pans which ride freely in a vertical plane in the guides; J, speed reducer; K, ¼-hp. electric driving motor; L, device for spreading yarns uniformly over the reel; M, yarn reel.

Figure 1 shows the miniature experimental slasher which was developed for and used in cooperative work with several textile mills to establish the value of sweet potato starch as a cotton warp sizing agent.

The warp for this slasher consists of three ends of yarn drawn from bobbins. After passing under tension disks, the ends pass through a starch immersion bath and then between a drive roll and a squeeze roll. The drive roll is driven by a gear attached to the roll shaft, which in turn is driven through a train of reducing gears by an electric motor. From the rolls the ends pass over a traverse-motion device which spaces them uniformly on the reel. The traverse-motion and the reel are driven by a belt from the motor-driven reducer.

It will be noticed that a steam chest, heated by a gas burner, makes up the lower part of the starch vat. Steam from this source is used to heat both the starch vat and the driving cylinder during slashing. Steam can be passed through the hollow driving cylinder. Pressure on the squeeze roll is regulated by weights placed on the pans which rest on the bearings of the squeeze roll.

A one-gallon metal ice cream container and cover, fitted with a motor-driven paddle agitator, externally heated in an oil bath, is used to cook the starch mixtures. Sized yarns are dried on the reel in an ordinary hot-air dryer.

Design of the slasher, with two possible exceptions, resembles that of the commercial slasher commonly used in this country. The exceptions are that sized yarns are dried in hot air rather than over steam heated cylinders, and that the starch mixture in the kettle is heated externally rather than directly with live steam.

Since drying cans complicate the operation and at best are expensive, an air dryer is used. It is believed that hot-air dried and cylinder-dried yarns have, for all practical experimental purposes, the same physical properties, provided both have been dried to the same moisture content and under equivalent conditions, i.e., rate of drying, tension, etc.

The externally heated starch kettle is used because in small-scale experimentation such heating gives greater control and flexibility to the operation. A starch mixture gelatinized and cooked in a small externally heated starch kettle is practically identical to a similar mixture cooked by live steam in a commercial starch kettle, provided the same formulae were used and the solid contents and viscosities of the finished mixtures were identical.

Individual slashers, as well as operating conditons used in commercial practice, may vary considerably in different mills. However, it was found possible to adjust the small slasher so that a yarn of definite count, sized thereon with a given starch mixture, took up a percentage of starch equivalent to that taken up by a yarn of like count, similarly sized on a commercial slasher. For example, yarn sized on one particular mill slasher contained an average size content of 13.7 per cent. With a squeeze roll weighting of 210 ounces the small slasher delivered yarn with an average of 13.6 per cent size content. Breaking strength and stretch determinations of the yarns sized on the mill slasher and on the small slasher were not greatly different.

TESTING THE SIZED YARNS

After the miniature slasher was calibrated the next step was to develop methods and apparatus for testing the sized yarns. In general cotton mill slasher practice there were no definite tests, with the exception of strength and "feel", whereby a sized yarn could be judged as "good" or "bad", suitable", or "unsuitable". Hence, to terminate the value of a sizing agent, it became necessary first to ascertain the characteristics which a properly sized yarn should possess. With these in mind the comparable merits of the various sizing materials could be determined in their ability to impart these properties to yarns.

From a weaving standpoint, properly sized yarns should possess certain qualities. Short discussions of some of the more important ones are as follows:

(1) **Tensile Strength.**—This should be sufficient to withstand the pulling action of the loom and minimize breaks during weaving. A good sizing material, when properly applied to the raw yarn, will build up the breaking strength of the yarn. In these tests the breaking strength was measured in ounces and the tests were made on the regular Alfred Sutter single-strand tester, the jaws of which were eighteen inches apart at the beginning of the test. The speed of the pulling jaw was twelve inches per minute.

(2) **Elongation or Stretch at Break.**—There is a tendency for sizing to decrease the stretch of a yarn to some degree. This decrease is a disadvantage when in excess in that the yarns lose their elasticity to a certain extent, i.e., there is very little "give" before the yarn breaks when subjected to the extra strain of the loom[1]. A good sizing agent should, it seems, cause a minimum change in the elongation or stretch property of yarn.

These stretch tests were also made on the Alfred Sutter single-strand tester which automatically records the per cent stretch or elongation at break of a yarn which is being tested for breaking strength.

(3) **Resistance to Abrasion.**—The author believes that one of the important functions of size on a yarn is the increased resistance to abrasion imparted to the yarn. This increased abrasive resistance is necessary for the yarn to withstand the abrasive action of the many moving parts of the loom which come in contact with it during the weaving process. There are several theories, which now are fairly well established, concerning the part sizing plays in increasing the abrasive resistance of yarns. It is believed that the properly applied size not only increases the tensile strength of the yarn by the weight of the size added to the body of the yarn, but also cements the many fibers together and at the same time plasters the "fuzzy" outer fibers down and forms a protective surface coating.

A maximum amount of this abrasive-resistance quality is desired in a sized yarn without excessive minimization of certain other qualities such as softness, flexibility, elasticity, etc. For this reason size formulae are usually worked out containing not only starch, which is the principal ingredient, but also softeners, lubricators, etc.

Figure 2 shows the laboratory abrading machine which was used to subject the yarn specimen to a definite amount of abrasion. The

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[1]"Handbook on Cotton Warp Sizing"—E. F. Houghton, p. 73, Houghton Textile Research Staff, E. F. Houghton and Company, Philadelphia, Pennsylvania.

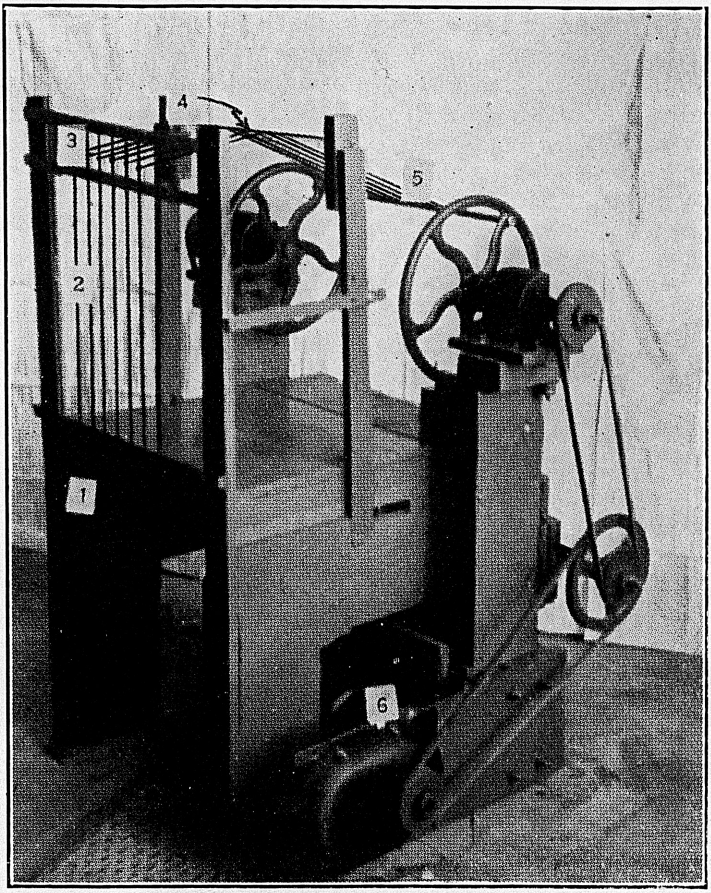

FIGURE 2.—Machine for Abrading Yarns.

1, Weights on lower ends of specimens, 20 grams each; 2, yarn specimens; 3, heddle eyes; 4, guide bar to maintain constant angle at heddle eye; 5, driving bar; and 6, driving mechanism.

(NOTE.—This machine may be provided with a handle for hand operation.)

samples to be abraded were fastened in the machine as shown and as the machine was operated the oscillatory motion of the bar between the large revolving wheels imparted a smooth back-and-forth movement to the specimens. This movement in turn caused a given length (11½ inches in this particular set-up) of the samples to be abraded by frictional contact as they passed back and forth through the heddle eyes. It will be noted that the yarn was at the same time under a definite load of 20 grams applied by the travelling weights attached to the end of the samples, and by the arrangement was such that the yarns were not free to lose any twist during the abrasion.

(4) **Stiffness**[1].—When sizing is applied to a yarn it imparts a certain amount of stiffness. The amount or degree of stiffness imparted is dependent upon several factors, namely: consistency of sizing mixture at the time of slashing, amount of softeners added to the sizing mixture, and degree of moisture allowed to remain in the sized yarn upon driving.

It has not been fully established just what bearing stiffness has upon a properly sized yarn, however, stiffness plays a major part in giving a sized yarn that proper "feel" which means so much to the mill man. It would seem that a yarn that is "stiff" to a reasonable degree would afford better weaving in that there would be less tendency on the part of the yarn to snarl and kink during the weaving operation. The degree of stiffness must, however, not be so great as to prevent the yarn being pliable.

The stiffness-testing apparatus consisted of a set of rubber covered rolls through which the yarn sample was passed in a horizontal plane and a shelf fastened at a 45-degree angle with the vertical at the zero reading of the scale. The scale was graduated in inches and readings were taken at the point where the free end of the sized yarn specimen just touched the scale.

SWEET POTATO STARCH COMPARED WITH A HIGH-GRADE COMMERCIAL STARCH AS A WARP SIZING AGENT[2]

In order to determine the effectiveness of sweet potato starch as a cotton warp sizing agent, several different yarn samples were sized with it and compared with similar yarns sized with a high-grade commercial starch. In both instances the slashing conditions were maintained as nearly the same as possible.

Table 1 shows the results of testing the above sized yarns. It will be noticed that though the per cent starch imparted to the yarns was less in the case of sweet potato starch sizing, the tensile strength of those yarns was higher than of the yarns sized with the high-grade commercial starch. The per cent stretch of the yarns sized with sweet potato starch was changed less from the stretch of the original than those sized with the commercial starch. The stiffness of the variously sized yarns was increased over that of the unsized yarns in both cases.

Table 2 shows the same comparisons as Table 1, except that five per cent tallow (by weight of starch used) was added to the starch size mixture before cooking.

The results as shown in Table 2 are very analogous to those of Table 1. The presence of the tallow seemed to "tone down" the stiffness of the yarn sized with the commercial starch to a small degree.

Both Tables 1 and 2 show that for comparable results and effectiveness, lower concentrations of sweet potato starch are required than where the commercial starch is used.

[1]"Stiffness of Fabrics Produced by Different Starches and Starch Mixtures and a Quantitative Method for Evaluating Stiffness", by Peterson and Dantzig, U.S. Department of Agriculture, Technical Bulletin 108.

[2]All data reported were obtained from tests carried out on yarn samples sized on a commercial slasher which had been adapted to experimental work.

TABLE 1.—Comparison of the Effectiveness of Sweet Potato Starch and a High-Grade Commercial Starch as Cotton Warp Sizing Agents.

Sizing agent used	Sized sample number	Time of cooking size (Min.)	Consistency[1] of size mixture at time of slashing	Starch on sized yarn (Per cent)	Tensile strength sized yarn (Oz.)	Stretch at break (Per cent)	Stiffness of sized yarn (Inches)
Sweet Potato Starch	97-B	120	60	6.56	19.22	4.25	6.08
	98-B	180	31	4.70	19.10	4.20	5.02
	99-B	240	25	3.59	17.37	4.00	4.67
A High-Grade Commercial Starch	122-B	120	135	10.87	17.70	4.00	6.24
	123-B	180	50	6.97	16.70	3.60	6.13
	124-B	240	36	5.20	15.70	3.30	5.44
Unsized or raw yarn					11.92	5.50	2.50

Legend

Size Cook Concentration—10 per cent starch by weight
Size Vat Temperature—205°F.
Size Pot Temperature—180°F.
Cylinder Temperature—214° - 224°F.
Weight of Squeeze Roll—210 lbs.
Speed of Yarn Travel—2 feet per second
Count of Yarn Sized—20s cotton warp yarn

[1]Consistency was the time of flow in seconds of 20 cc. through the orifice of a Standard Saybolt Viscosimeter.

TABLE 2.—Comparison of the Effectiveness of Sweet Potato Starch and a High-Grade Commercial Starch as Cotton Warp Sizing Agents When a Softener[1] Was Added to the Sizing Mixture.

Sizing agent used	Sized sample number	Time of cooking size (Min.)	Consistency[2] of size at time of slashing	Starch on sized yarn (per cent)	Tensile strength sized yarn (Oz.)	Stretch at break (Per cent)	Stiffness of sized yarn (Inches)
Sweet Potato Starch and Tallow	116-B	120	110	9.45	16.60	4.20	6.10
	117-B	180	43	6.72	17.17	4.07	5.78
	118-B	240	29	4.77	17.22	4.15	4.87
High-Grade Commercial Starch and Tallow	125-B	120	120	11.25	16.00	3.80	5.91
	126-B	180	50	7.47	16.70	3.80	5.75
	127-B	240	36	6.22	15.20	3.90	5.55
Unsized or raw yarn					11.92	5.50	2.50

Legend

Size Cook Concentration—10 per cent Starch (plus tallow)
Size Vat Temperature—205°F.
Size Pot Temperature—180°F.
Cylinder Temperature—214° - 224°F.
Weight of Squeeze Roll—210 lbs.
Speed of Yarn Travel—2 feet per second
Count of Yarn Sized—20s cotton warp yarn

[1]Softener added to sizing mixture was 5 per cent tallow by weight of starch used.
[2]Consistency was the time of flow in seconds of 20 cc. of the sizing mixture through the orifice of a Standard Saybolt Viscosimeter.
(All results reported were averages of sixteen individual determinations.)

EFFECTIVENESS OF SWEET POTATO STARCH AS A COTTON WARP SIZING AGENT UPON PROLONGED COOKING OF THE MIXTURE

Since it is often necessary in actual mill slashing to cook the size mixture for an extended length of time before a given length of yarn can be complete in the sizing operation, it was deemed worthwhile to try out sweet potato starch size over a prolonged cooking period.

Table 3 shows the effectiveness of sweet potato starch as a sizing agent after prolonged cooking of the size mixture.

A sizing mixture containing 14 per cent sweet potato starch was prepared and cooked for a duration of eight hours. Warp yarn samples were slashed at intervals of 2, 3, 4, 6, and 8 hours of cooking.

Results of these tests showed that sweet potato starch was very effective as a warp sizing agent after being cooked six hours and remained fairly good through eight hours of cooking.

TABLE 3.—Effectiveness of Sweet Potato Starch as a Cotton Warp Sizing Agent upon Prolonged Cooking of the Mixture.

Sized sample number	Time of cooking mixture (Min.)	Consistency[1] of mixture at time of slashing	Starch on sized yarn (Per cent)	Tensile strength sized yarn (Oz.)	Stretch at break (Per cent)	Stiffness of sized yarn (Inches)
100	120	240	12.45	18.70	4.15	6.80
101	180	98	7.37	18.42	4.30	6.17
102	240	60	6.15	17.17	4.85	6.17
108	360	43	5.66	17.05	3.92	5.07
109	480	21	4.83	15.95	3.85	3.60
Unsized or raw yarn				11.92	5.50	2.50

Legend

Cook Concentration—14 per cent sweet potato starch
Size Vat Temperature—205°F.
Size Pot Temperature—180°F.
Cylinder Temperature—214° - 224°F.
Weight of Squeeze Roll—210 lbs.
Speed of Yarn Travel—2 feet per second.
Count of Yarn Sized—20s cotton warp yarn.

[1]Contsistency was the time of flow in seconds of 20 cc. of the sizing mixture through the orifice of a Standard Saybolt Viscosimeter.

THE EFFECT OF ABRASION ON VARIOUSLY SIZED COTTON WARP YARNS

Sized yarns of various starch content were tested prior to abrasion and after being exposed to six and sixteen strokes in the laboratory abrading machine respectively.

Table 4 gives the results of these experiments. A perusal of the table will show that yarns sized with sweet potato starch withstood abrasion as well as, and in some instances better than, those sized with a high-grade commercial starch.

TABLE 4.—The Effect of Abrasion on Variously Sized Cotton Warp Yarns.

Sized sample number	Starch of sized yarn (Per cent)	Tensile Strength (Oz.)			Stretch (Per cent)		
		Abraded none	Abraded six strokes	Abraded sixteen strokes	Abraded none	Abraded six strokes	Abraded sixteen strokes
(Samples below sized with sweet potato starch)							
116-B	9.45	16.60	15.75	15.04	4.20	4.91	5.08
116-A	9.11	17.65	15.41	14.08	4.05	4.50	4.71
116-C	9.00	16.55	15.21	14.41	4.60	4.91	5.05
101-C	8.80	17.87	17.16	17.33	4.35	4.65	4.58
101-B	8.37	18.30	16.04	16.04	4.30	4.12	4.08
115-C	8.10	17.12	14.96	16.54	3.83	4.54	4.66
103-A	5.68	16.55	15.55	15.67	4.34	4.40	4.58
103-B	5.55	16.87	15.37	15.00	4.11	3.81	4.33
103-C	5.52	16.15	15.83	15.46	4.02	4.37	4.83
(Samples below sized with a high-grade commercial starch)							
125-B	11.25	16.00	15.46	15.04	3.80	4.46	4.25
122-B	10.87	17.70	16.40	15.40	4.00	4.00	4.01
126-C	9.00	16.80	15.66	13.75	4.30	4.83	4.25
126-B	7.47	16.70	16.04	15.41	3.80	4.96	4.90
123-B	6.97	16.70	16.66	16.58	3.60	4.71	4.79
127-A	6.22	15.90	15.25	14.04	3.90	4.83	4.46
124-A	5.20	15.70	15.79	15.41	3.30	4.54	4.79
Unsized yarn		11.92	9.45	8.96	5.50	5.95	6.50

PLANT SCALE TESTS

To verify the conclusions deducted from the semi-plant works and tests made in the laboratory, several plant-scale tests were made. At the mill of the Pepperell Manufacturing Company located at Opelika, Alabama, which is near the Alabama Polytechnic Institute, several cuts of 13½s and 32s cotton warps were sized, using sweet potato starch under mill conditions of operation. These warps were then woven into cloth. The quality of this cloth was satisfactory, and no difficulties were encountered in the weaving operation. Further, broadcloth produced from the finer yarns was desized, dyed, and finished. This final product appeared equal to similarly processed cloth which had been sized with a high-grade commercial starch[1].

Another large Southern cotton mill, operating 800 looms, has been using sweet potato starch exclusively since May 1936. It uses more than two tons of starch a week. Among the tests made by this mill was one in which 48 looms were operated on a comparison test for four full weeks. Half of the forty-eight looms used warp yarns sized with sweet potato starch while the other twenty-four used yarns sized with starch similar to that used by the mill for years. There were less stops on the looms using the sweet potato starch sizing than on the other looms. And loom stops are the things that mill people fight because they stop production and profit[2].

[1]"Sweet Potato Starch Makes Good Size"—W. T. Schreiber, Textile World, September, 1935.

[2]"Sweet Potato Starch—A New Farm Industry for the South"—Henry G. Knight, Manufacturers' Record, February, 1937.

It is also of interest to know that located at Laurel, Mississippi, is a commercial sweet potato starch plant. This project was begun in 1934 by an allotment of $150,000 from the Federal Emergency Administration, the plant being located in an abandoned saw mill. In 1934, 140,000 pounds of starch were produced. This was increased to 250,000 pounds in 1935 and since then the output has gone beyond a half million pounds per working season of 100 days. Along with this increase in production the cost of manufacturing has dropped from 13 cents per pound to less than 3 cents per pound[1].

CONCLUSIONS

1. Various tests were developed for the evaluation of starch as a sizing agent for cotton.

2. On the basis of these tests, and other tests, sweet potato starch is equal to and in some respects superior to a high-grade commercial starch as a warp sizing agent.

3. Recognition of the good qualities of sweet potato starch should lead to further use of this product in the South.

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[1] "Sweet Potato Starch—A New Farm Industry for the South"—Henry G. Knight, Manufacturers' Record, February, 1937.