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SEPARATION OF CORNSTALKS INTO LONG FIBERS, PITH, AND FINES

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ABSTRACT

The wet method of separating pith from cornstalks was modified to produce three fractions of useful materials.

The method consisted in a preliminary coarse shredding, preferably in a wet condition to minimize the production of fine material, washing the shredded material with water to remove most of the loose dirt, breaking the pith free from the shell and inner fibers by a wet mechanical treatment, separating the pith, "fines", and dirt from the long fibers by wet screening, and separating the pith from the fines and dirt by water flotation.

Data on the ash of the various fractions and the thermal conductivities of pith and pith board are given, together with a discussion of the uses to which the materials may be put. The yields are 42.5 percent of long fiber, 5 percent of pith, and 22.5 percent of fines.

CONTENTS

I. INTRODUCTION

For a number of years, the National Bureau of Standards, in cooperation with the Engineering Experiment Station of Iowa State College, conducted investigations on agricultural wastes as a source of papermaking fibers. One of these annual wastes studied was cornstalks.

Experiments with cornstalks soon made it evident that the physical characteristics of different portions of the stalks cause different degrees of reactivity to the same chemical or mechanical treatment. A separation of these parts would simplify the pulping process of the material more suitable for papermaking fiber.

The stalks can be separated into two main constituents, the outer shell, which contains fibers suitable for papermaking, and the parenchymatous tissue or pith. Two general methods for the separation have been investigated, the dry and the wet. The dry method, patented [1] in 1899, cut the pith free from the outer shell with a special machine. The wet method [2] was used by workers in plant chemistry investigations [3] and by G. N. Seidel, a member of the Bureau staff, working on insulation lumber from cornstalks. The wet method consisted in breaking the pith loose from the shell in a beater, screening the pith through a no. 8 screen fastened to a rotary washer, and collecting the pith on a fine screen. The breaking and screening were accomplished in the presence of water. This method produced a good separation of the constituents and had the advantage over the dry method of producing an outer-shell fiber free from dirt as well as from leaf membrane. The method, however, was slow and made no attempt to separate the dirt and fine material from the pith.

The following method is a modification of the wet method and separates the stalks into three fractions.

II. MECHANICAL SEPARATION

The mechanical separation consists in preliminary shredding and washing of the stalks followed by operations which break the pith free from the fiber, screen the pith and other materials from the fibers with water, and separate the pith from the fines and dirt by flotation in water.

1. SHREDDING

The baled stalks were broken open and fed into an ensilage cutter fitted with 12-inch blades. The stalks were reduced to lengths of from 1 to 3 inches at the rate of 300 pounds per hour. In this work, the stalks were shredded in an air-dried condition since it was necessary to store the material for some time. In practice, it would be better to shred the stalks wet to reduce the formation of fine, broken fiber that would be lost in the subsequent washing treatments.

2. WASHING

Sixty pounds of shredded stalks were added to 250 gallons of water in a 300-gallon thresher tank, figure 1. The mixture was agitated for 10 minutes, agitation stopped, and the water drained, leaving the stalks in the tank. Fresh water was added, the mixture agitated, and then drained as before. When the agitator was stationary, most of the stalks rose to the top of the water and permitted a large proportion of the water to be discharged before a mat of stalks formed over the outlet pipe. The small amount of stalks passing through the discharge pipe was caught on a no. 4 screen and returned to the tank. This was repeated until the wash water was practically clear, requiring 4 to 5 washes. In the last step, the agitator was kept in motion to permit the stalks to discharge with the water. The stalks were collected behind the removable grating shown in figure 1.

This prewashing of the stalks is advisable to remove most of the dirt and prevent its being ground into the fibers by the action of the attrition mill in the next step. Mechanical dusting of the stalks will not remove the dirt as effectively as wet washing unless the stalks are dry.

[1] G. R. Sherwood, U. S. patent, no. 627882.
[2] H. Kumagama and K. Shimomura, British patent no. 299740; Chem. Abs. 23, 3574 (1929).
[3] C. J. Peterson, E. H. C. Fang, and R. M. Hixon, Iowa State Coll. J. Sci. 7, 17–24 (1932).

3. BREAKING

The washed stalks were passed through a 24-inch attrition mill at the rate of 100 pounds per hour together with water at 30 gallons per minute. The discharge of loosened pith and long fiber bundles was caught on a no. 30 screen. The attrition mill proved to be the best type of mill for producing the desired action. The mill consisted of two corrugated steel disks mounted on horizontal shafts. The disks revolved in opposite directions at 1,800 rpm and were enclosed in a steel shell. Pressure was exerted on the adjacent faces of the disks by springs attached to the shaft of one of them. The compression in the springs was regulated by an adjusting screw. The feed was made through a hopper connecting to openings around the shaft of the non-adjustable disk. The tension of the springs of the attrition mill was

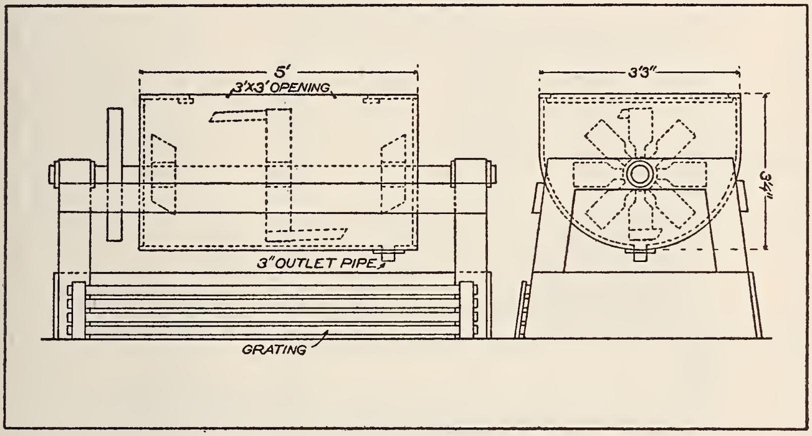

FIGURE 1.—*Thresher tank.*

adjusted to give the least cutting action on the fibers and still break the pith free. The breaking operation also loosened the residual dirt in the stalks.

4. SEPARATION OF LONG FIBER

One hundred pounds, dry weight, of the milled stalks were transferred to the thresher tank and the screening hopper, figure 2, was fitted tightly into the top opening of the tank. A continuous stream of water, 10 gallons per minute, and a small amount of compressed air were introduced into the bottom of the tank. The water, under continuous agitation, carried the pith, fines, and dirt through the screen, D, and into the hopper trough, A, where it was discharged through B into the pith separating barrels. The operation required about 90 minutes. At the end of the separation, the long fiber, consisting chiefly of cortex and practically free of pith, fines, and dirt, was discharged in the same manner as the washed stalks.

The screening hopper, figure 2, consisted of wooden side walls partially covered by a galvanized-iron top, C. Spaced beneath the top was 6 square feet of no. 4 galvanized-iron screening, D. The screen was attached to the walls and to the top of the wall adjacent to the solid-bottomed discharge trough, A. The agitator paddles in the thresher tank worked counter-clockwise, considering the end view in figure 1, and caused the charge to flow from the back toward the front at the screen surface.

5. SEPARATION OF PITH AND FINES

The overflow water, carrying the pith and fines, was led into the top of a 50-gallon barrel, about 18 inches in diameter, illustrated in figure 3, which shows the details of the separation. From the side-wall pipe, the water was led into a 100-gallon barrel, about 23 inches in diameter, and then into a box with a no. 30 screen bottom. The settled fines were washed from the barrels at the end of 2 or 3 charges of milled stalks. Practically all of the pith was recovered from the top of the first barrel.

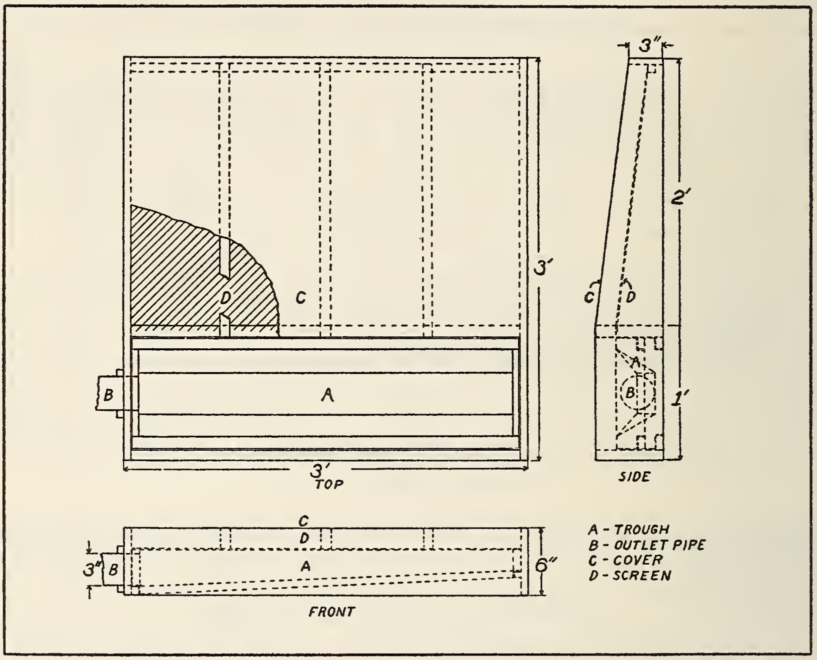

FIGURE 2.—*Screening hopper.*

The separation depends upon the fact that the fines will water-log more readily than the pith during the process and will settle in water while the pith floats. Figure 3 is a schematic representation of the present set-up of the flotation process. Figure 4 is a proposed modification of the arrangement. The reversal of the sizes of the settling tanks is in order to have a greater capacity for settling in the first step. It will be noticed in the representation of materials gathered, figure 3, that the first settling contains practically no water-logged pith. Unless there is to be a further separation of the water-logged pith and the short fibers or a differential use of the two types of fines, it would be more logical to have the main settling area in the first step. Further experimentation with the correct rate of flow of water through this area might lead to the elimination of the second tank entirely.

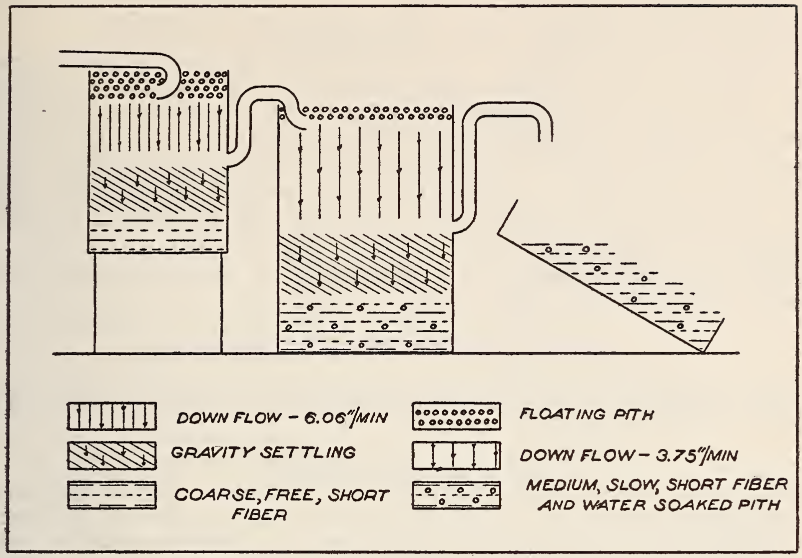

FIGURE 3.—*Present system of pith flotation.*

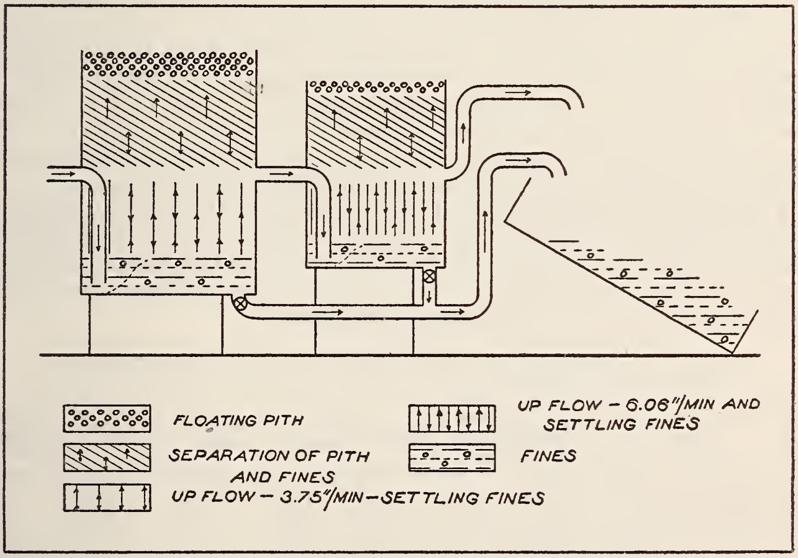

FIGURE 4.—*Suggested system of pith flotation.*

III. HANDLING OF PRODUCTS

The long fiber from the separation process is ready for processing into papermaking fibers, etc., without additional treatment.

The pith can be utilized in a wet condition for some purposes, but for others it must be dried. The pith recovered from the top of the flotation barrels contains about 95 percent of moisture, which is reduced to 60 or 70 percent by subjecting sacks of the material to a pressure of 400 pounds per square inch. The pressed pith is then fluffed out by passing it rapidly through a swing-hammer mill. The final drying is accomplished by a current of hot air over or through thin layers of the pith.

The fines, when desired in a dry condition, can be treated in a manner similar to the pith.

IV. ANALYSES OF THE MATERIALS

The efficiency of the operation in removing the dirt from the cornstalks is as follows:

Ash in the various fractions

Material:	*Ash (percent)*
Shredded stalks	[4] 6. 1
Long fibers	2. 9
Pith	[5] 4. 0
Fines	6. 2

[4] O. R. Sweeney and L. K. Arnold, Iowa State Coll. Exp. Sta. Bul. no. 98 (1930), list data showing the ash of cornstalks to vary from 3.6 to 10.5 percent.

[5] H. W. Wiley, U. S. Dept. Agr. Chem. Bul. no. 50 (1898), gives the ash of pith as 4.52 percent.

The average content of ash in the combined long fiber and pith amounts to 3 percent, and, considering that in the cornstalks there is present constituent ash amounting to about 2 percent, it is evident that most of the dirt has been removed from these fractions. The high ash content in the fines is to be expected as the dirt loosened during the attrition mill treatment will settle with the fines.

A partial chemical analysis of the different portions of cornstalks is given in table 1. These data were reported by Hooper [6] and indicate that the chemical difference in the pith, vascular bundles, and shell is small and that their differences in properties are "largely due to the original mechanical subdivision of the tissues".

TABLE 1.—*Composition of shell, pith, and inner vascular bundles*

Tissue	Specific gravity at 25° C	Lignins	Pentosans	Cellulosic pulp	Pentosans in pulp	Cellulose by difference
Pith	1. 52	32. 0	27. 7	50. 1	12. 2	37. 9
Inner vascular bundles	1. 515	35. 2	26. 4	50. 2	13. 1	37. 1
Shell	1. 52	33. 5	25. 9	55. 9	16. 6	39. 3

The yields of materials obtained by the wet separation process are given in table 2, together with yield data presented by Peterson Fang, and Hixon,[7] using the wet separation with a beater.

[6] F. E. Hooper, Plant Physiol. 6, 531–539 (1931) table 1, p. 536.

[7] C. J. Peterson, E. H. Fang, and R. M. Hixon, Iowa State Coll. J. Sci. 7, 17–34 (1932).

Table 2.—*Yields of fractions in the wet separation of cornstalks*

Wet separation method [1]		Wet separation with a beater [2]	
Material	Percent	Material	Percent
Long fiber	42.5	Fibrous material	63
Pith	5.0	Pith material	26
Fines	22.5	Water soluble	9
Loss	30.0	Loss and difference	2

[1] Data obtained in this investigation.
[2] Data obtained by Peterson, Fang, and Hixon. (See footnote 7.)

The two sets of data do not agree. There are a number of reasons for this disagreement. The stalks used by Peterson, Fang, and Hixon were freed from leaves and loose dirt before the separation was begun, the separation was performed on small batches of 1 to 2 pounds of stalks and the fraction reported by them as pith material was the material passing through a no. 10 screen and retained on a no. 60 screen. Wiley,[8] on the other hand, gives the yield of pith from the whole cornstalk, not including the corn or cob, as 10.3 percent.

The size of the batches used in this investigation was between 100 and 200 pounds and consequently offered opportunities for errors in sampling the wet masses. The authors made one yield determination on the beater method on a large scale, starting with approximately 100 pounds, in which the stalks were separated into three fractions. The results of this run gave a 70-percent recovery and indicated that the beater and attrition mill methods were comparable on a large scale. The products from these two methods were quite similar. The disadvantage of using a beater lies in its high consumption of power compared with the combined power used by the attrition mill and the separating tank.

V. COST AND USES

The cost and yield figures are given in table 3. The power costs are based on power consumed by the small equipment used in the experimental work. The water costs are based on pumping and filtering the volume of water used since fresh water would be expensive at ordinary prices.

Table 3.—*Cost data*

	Stalks	Long fiber	Pith	Fines
Tons	1.00	0.425	0.05	0.225
Power at 1 cent a kilowatt hour		$0.75	$0.09	$0.40
Water at 0.8 cent a 1,000 gallons		.38	.05	.20
Fuel for drying			.15	.69
Total		1.18	.29	1.29
Cost a ton	$2.76	2.65	5.90	5.73

[8] H. W. Wiley, U. S. Dept. Agr. Chem. Bul. no. 50 (1898), gives the ash of pith as 4.52 percent.

To these costs would have to be added those for labor, raw material, overhead, etc. The values given in table 3 have been apportioned between the three products according to the weight of each.

The three components of cornstalks have many possibilities for utilization in industry. The chemical analysis of each fraction is very nearly the same, but the differences in physical characteristics give them a wide range of usefulness. The long fiber, after suitable treatment, has the possibility of economical use in making paper, insulation board, and pressboard. The pith has interesting possibilities as an insulating material. Tests by the heat and power division of the National Bureau of Standards indicate that its thermal conductivity is as low as that of cork, while its density is much less. In a wet condition the pith can be beaten, molded into boards or blocks and dried. These boards have approximately the same thermal conductivity as the original material, but with a greater density. In the granular and molded forms pith can be used as insulation material in refrigerators, refrigeration cars, house insulation, and because of its low density it might find application in airplane insulation. Further, it might find an outlet as a substitute for ground cork in the manufacture of linoleum. Pith is easily nitrated and it is possible that it might be valuable as a raw material for the manufacture of explosives.

The fines should find outlets as material for pressboard, insulating material, and possibly as a substitute for wood flour in the manufacture of linoleum.

The authors acknowledge their appreciation for the cooperation and the assistance of the members of the staff of the Iowa State College Experiment Station in this work; particularly to Dr. O. R. Sweeney, in whose laboratory the work was carried out, and to Charles W. Miller for his assistance and suggestions in the actual experimental work.

WASHINGTON, January 12, 1935.

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