6-1982

Evaluation of Helianthus Turberosus as an Alternative Fiber Source

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EVALUATION OF HELIANTHUS TURBEROSUS
AS AN ALTERNATIVE FIBER SOURCE

by
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A Thesis Submitted
in partial fulfillment of
the course requirements for
the Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan
June, 1982

ACKNOLWEDGEMENTS

I would like to thank my advisor, Robert Kinsey, Richard Valley and Lyman Aldrich for their information and time; Al Coburn for growing the material and sending it; Bob Peck and Gayl Stuut for their help in making this work complete; and especially my fiancee, Alison Londahl, for love and understanding.

ABSTRACT

Depithing of Helianthus Tuberosus was performed for one and five minutes in a Morden Slush Maker at 115^{o}C and 7% consistency. The pith and fines were removed, leaving the woody chips. The chips were pulped using sodium hydroxide in a bomb digestor at a five to one liquor to wood ratio using 20% active alkali for one hour at 170^{o}C. The resulting chips were fiberized and handsheets were made according to Noble and Wood procedures. The handsheets were tested and reported.

The resulting fibers show little promise for use in papers requiring high tensile or tear.

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INTRODUCTION

With the increasing need for energy resources from within the country, we are constantly searching for nonexhaustable or renewable sources to meet this need. One result of the search is Halianthus Tuberosus, or the Jerusalem Artichoke. It has been determined by the National Alcohol Fuels Information Center in Golden, Colorado, that an acre of Jerusalem Artichokes is capable of producing 1200 gallons of alcohol compared to corn which produces only 214 gallons per acre. In addition to the use of the tubers for alcohol production, the leaves and seeds can be used as a food source and the stems as a source of fiber and fuel. It is my intention to use the stem as a source of papermaking fiber.

The Jerusalem Artichoke has been cultivated for food for hundreds of years and ranges from the eastern Atlantic states to the Rocky Mountains. Jerusalem Artichokes are perennial, grow from three to nine feet in hieght, and will survive in the worst conditions. The pith from Jerusalem Artichokes ranks as one of the lightest substances known with a specific gravity of 0.028, compared to cork with a specific gravity of 0.24. Although the Jerusalem Artichoke has been cultivated along with other sunflowers for some time now, little work has been done pulping or depithing methods for sunflowers.[1] Therefore, the basis for the majority of my work is based on bagasse depithing methods and bagasse pulping methods.

LITERATURE SEARCH

From the articles reviewed on laboratory pulping of bagasse, it appears as though there has been a fair amount of work performed in this area.

In Casey's section, "Pulping of Bagasse and Cornstalks", he identifies three steps in the cooking of bagasse. These steps are: 1) cutting of the bagasse into short pieces; 2) cooking in the presence of water; and 3) refining of the pulp. Casey also identifies caustic and acidic pulping procedures for bagasse. In the caustic process he states that 25% sodium hydroxide at a liquor ratio of five to one at 125 psi for six hours gave a good bleachable pulp with a yield of 34-35%. In the acidic process, bagasse is steeped in a 55% solution of nitric acid for one hour at 80^{o}C and yields of 42-46% can be obtained. Casey also notes the work by J. E. Atchison on pith removal of bagasse.[2]

In the article, "High Yield Pulps by Hot Caustic Soda Process", by V. N. Mukherjea and S. R. D. Guha[3], we find an alternative to pressurized cooks and extended times. Their method for pulping of bagasse at atmospheric pressure was boiling it for 15 to 30 minutes at 98^{o}C and a 5.5 to 1 liquor ratio. The reported yield was 70-80%. In the comparison of several articles, it was noticed that similar methods were used on rice straw as were used on bagasse. The pulp, by this method, had to be fiberized by a Banning beater or by some other mechanical process. The process used by Mukheriea and Guha lends itself quite well in application to this thesis, due to the small amount of capital and time required to produce a satisfactory pulp.

Work done by Peckham, Nicholls and VanDrunen[4] indicate that an effective method for pulping bagasse using bomb digestors can obtain yields in the 70-73% range using 8% sodium hydroxide at a bath temperature of 176°C for 12 minutes. This method of pulping also has a high potential for successful application to pulping of Jerusalem Artichokes in the laboratory due to the small chemical charge required and short cooking times.

It is not expected that the depithing and pulping methods that are successful for bagasse will be directly applicable to Jerusalem Artichokes. However, due to the similarities in the structure of the two plants, application of depithing and pulping methods to Jerusalem Artichokes should be easily applied from the data involving bagasse depithing and pulping.

The majority of the work on depithing of bagasse was performed by Lathrop, Naffziger and Mahon for the United States Department of Agriculture in 1955.[5] Although 25 years old, this article is the most complete work to date and is still frequently referenced. In their article they cover several methods for loosening the pith from the fiber, separating the loosened pith and fiber in a water suspension, and dewatering of the separated pith. They also cover the selection of a process of separation influenced by industrial factors, uses for whole bagasse, pith-free fiber, pith, and also the separation process applied to other materials.

Of particular interest to my thesis was the application of a hydropulper to depith the bagasse. In this section the authors outline optimum temperature, consistency, and other variables affecting the depithing operation. The authors concluded that the smoothest charging operation occurred when half the bagasse was added to two thirds of the water, then adding the remainder to achieve a consistency of 6.5-7%. Additional water was added to maintain a vortex. The authors determined that the optimum temperature range was 100-102^{o}F. The time of treatment was measured using a watt-meter curve. It was observed that during the depithing operation the power requirements reached a maximum and then fell to a minimum at the time when the pith had been removed from the fiber. The fiber and pith were then drawn through an 1/8" extraction plate.

In comparing the many wet screening methods attempted to separate the pith and fiber, the authors list three principles necessary for a satisfactory separation of pith and fiber. These principles are:

1. The screen design and operation must be such that fiber bundles will be carried parallel to the screen surface to prevent fiber bundles from nose diving through the perforations.

2. The fiber bundles must be kept in constant motion in order to wash the separated pith through the fiber and to convey the clean fiber out of the separation zone.

3. Since the movement of the pith during screening is downward through the perforations, it is necessary that the pith cells be thoroughly wetted.

The most successful wet screening operation was carried out by using a Jonsson screen having 0.25" hole screen at a consistency of 0.9-1.0%.

The authors also successfully used a flat screen at a consistency of 0.7-1.0% and screen plate having 0.19" holes. With this method however, they had difficulty in finding a suitable method of conveying fiber along the screen because of extreme dilution that occured with frequent washing. However, this is not a major concern to the success of the thesis. Other methods such as centri-cleaners or rotary screens proved to be inefficient compared to the Jonsson screen or flat screen. The authors determined that rescreening of the pith fraction was required to provide adequate pith and fiber separation using either the Jonsson or Flat screen.

From an article by Nieschlag Nelson Wolf and Perdue, we find Helianthus Tuberosus contains approximately 31.1% alpha cellulose and a 48.5% MEA cellulose. The bast fiber which consistutes 2.0% of the plant has a mean length of 1.31 mm and the woody fiber which constitutes 43.2% of the lant has a fiber length of 0.52 mm. According to their point system of evaluating the plant as a fiber source, it was given a score which indicates slight promise.

These articles sum up the relevant information on laboratory depithing and pulping of bagasse. It is from these procedures that I plan to approach the problem of producing a handsheet from the stalks of the Jerusalem Artichoke.

EXPERIMENTAL METHOD

In developing an experimental plan, three stages were designed to act as guideposts during the experiment. The three stages of the experiment are: 1) pre-pulping, 2) pulping, and 3) post pulping.

The pre-pulping stage covers all necessary preparations for the pulping stage. The data will be compared to similar data for bagasse, to determine if any deviations in the pulping procedure would be necessary. Secondly, the stalks will be prepared by removing leaves, roots and thin twigs, and cutting to a uniform length of 1½" by hand to eliminate nonuniform depithing. To achieve maximum depithing, a consistency of approximately 7% is recommended by Lathrop, Naffziger and Mahon. Using 75kg of stalks and pith will require 1071.4kg of H_2O to achieve a 7% consistency. A modified Waring blendor and a Morden Slushmaker will be compared in their ability to depith the stalk while minimizing the damage to the fibers. The temperature will be maintained at $110 \pm 10^{o}F$ using steam or hot H_2O for the entire run of 10-25 minutes. Visual inspection will aid in the determination of stalk - pith separation. Separation will be conducted on a laboratory flat screen using 1/8" holes at a consistency of 1.0%. The apparent fiber content, as a percentage of total discharge, will be calculated by dividing the dry weight of fiber by the total solids discharged. To insure maximum fiber recovery, the rejects will make a second pass on the flat screen to complete the fiber - pith separation. The resulting fiber will be dewatered and the moisture recorded.

The pulping trials will be performed in an oil bath digestor at a five to one ratio at 170^{o}C for one hour, and 20% active alkali. Several trials will be performed at varying conditions. It must be noted that the objective of this thesis is to investigate the potential of Jerusalem Artichokes as an alternative fiber source not to perfect the processes to obtain the fiber.

In the post pulping stage handsheets will be made according to the Noble and Wood procedure and tested for burts, tear, fold and brightness according to TAPPI Standards.

EXPERIMENTAL PROCEDURE

Upon arrival of the material from Texas, the Jerusalem Artichokes were sorted to eliminate any roots, leaves, or rotting material. The stalk was then soaked in water at room temperature overnight so that the stalks would be more pliable.

In preparation for depithing, the soaked stalk material was broken into three inch lengths and the larger diameter stalks were crushed to initiate the pith separation. This method also lessened the mechanical destruction experienced in the Morden Slush Maker.

The mechanical depithing was performed in the Morden Slush Maker at a temperature of $115^{o} \pm 5^{o}C$ and a consistency of 7% (O.D. material to water). Two depithing trials were performed. Trial one had a one minute residence time and trial two had a five minute residence time in the Morden. The water was heated to $115^{o}C$ by direct injection of steam. Due to the short times required in the Morden, there was very little temperature decrease.

After the required depithing times the water was drained, leaving the resulting woody chips, pith, and fines.

For each of the trials, the material was collected and diluted. The pith was removed by hand over a laboratory vibrating screen with 1/8" holes. The screen also served to remove the very fine woody chips and bark material (originally the outermost skin on the stalk). The remaining material was collected and the percent moisture determined.

A total of twelve bomb cooks were performed on the material. Four bomb cooks each were made on the cleaned and separated chips that resulted from the one minute and five minute Morden runs. Four bomb cooks were performed on material that was neither cleaned, nor had the pith removed. All of the cooks were at the same conditions. The pulping conditions were 20% active alkali on the wood at a five to one ratio at 170^{o}C for one hour. The bath was pre-heated to 100^{o}C before each cook.

At the end of one hour the bombs were removed and cooled to room temperature before opening. Upon opening the black lquor was drained off and collected. The chips were washed and then defibrated with three liters of H_2O for two to three minutes in a Waring blender at a speed setting of low.

The pulp was then dewatered on a Buchner Funnel, the moisture calculated and the yield determined. From the black liquor, the available alkali was determined and the alkali consumption calculated.

Handsheets were made according to the Noble and Wood procedure, and were then tested for brightness, basis weight, caliper, tear and density.

RESULTS

The results from the preliminary work performed on Jerusalem Artichokes show some promise for use in the pulp and paper industry.

From Table I we find that the yield was the highest with cleaning a large chip size. Yield decreased slightly with a decreased chip size. Yield was significantly decreased when there was no cleaning performed on trial one and the material was pulped with the pith and fines included.

TABLE I

	PULP TRIAL I	PULP TRIAL II	PULP TRIAL III
YIELD	75%	68%	40%

From Table II, we find that the greatest amount of alkali consumed was 98.85 grams/liter of alkali and the second pulp trial consumed 98.35 grams/liter of alkali.

TABLE II

	W.L. ALKALI GRAMS/LITER	B.L. ALKALI GRAMS/LITER	ALKALI CONSUMED GRAMS/LITER
PULP TRIAL I	111.6	23.63	87.97
PULP TRIAL II	111.6	13.25	98.35
PULP TRIAL III	111.6	12.75	98.85

From Table III, it is evident that the first pulp trial gave the highest burst, and the lowest tear and density. The third pulp trial gave the lowest burst and the highest density and tear. The second pulp trial gave values that were between the first and second pulp trials. Table III also shows that brightness remained fairly consistent throughout the three trials, although the third trial showed a slight increase.

TABLE III

	BASIS WEIGHT GRAMS/ METER^2	BURST PSI	TEAR GRAMS/ SHEET	BRIGHTNESS	DENSITY GRAMS/ METER^3
PULP TRIAL I	65.3	17.0	3.2	25.0	0.412
PULP TRIAL II	65.3	16.4	3.84	25.6	0.435
PULP TRIAL III	65.3	15.0	4.48	28.0	0.442

The two major problems encountered were the separation of the pith and chips and the foam that resulted from defibrating the cooked chips.

Physical separation of the pith from the stalk material was easily accomplished in the Morden Slushmaker, although separation of the two fractions proved more difficult.

Foam generation was a problem especially in the third trial.

DISCUSSION

A larger chip size is beneficial to the pulping process. From Table IV we find that the first pulp trial had the lowest amount of alkali consumed, the highest burst, and the highest yield. Minimizing the mechanical action during depithing in the Morden Slush Maker prevents the formation of fines and/or smaller chips which increases the alkali consumption and at the same time reduces yield. The fines that result from increased mechanical action during depithing allow the sheet to fill in voids within the sheet, thus increasing the density of the sheet and increasing its resistance to tear as shown in Table IV. The time and amount of mechanical action also affects such factors as the pith shape and size, and the separation of the pith from its woody counterpart. By visual inspection, we determined that one minute was adequate time to effectively separate the pith from the woody fraction, although the pith size was generally quite large. The large pith size does not facilitate removal by mechanical action because the screen hole size for the vibrating or fink screen required to pass the pith would also allow some of the woody fraction to pass.

TABLE IV

	ALKALI CONSUMPTION	BURST	BRIGHTNESS	TEAR	DENSITY	FOAM
PULP TRIAL I	87.97	17.0	25.0	3.2	.412	Moderate
PULP TRIAL II	89.35	16.4	25.6	3.8	.435	Moderate

After five minutes of mechanical action, the pith had been reduced in size, but the pulp yield had decreased and the alkali consumption had increased. An optimal situation would be a large chip size and small pith size. In keeping a large stalk chip size there is also a larger pith size. The larger pith size was too large to permit passage through the 1/8" holed vibrating screen. Also, the larger pith size took substantially longer to absorb water. The absorbtion process causes the pith to sink. Therefore, we separated the pith by hand screening over the vibrating screen. The result was a very clean stalk fraction and a very clean pith fraction.

The removal of pith and fines from the chips prior to pulping provides higher burst, lower fines decreased alkali consumption and lower foam generation as shown in Table V. The first and third pulp trials had essentially the same size chips. The difference lies in the fact that the third pulp trial material contained pith, fines and other non-fibrous material. In Table V we can see that the pith, fines, etc. show up in the form of increased sheet density, which is responsible for increased tear, increased alkali consumption, lower yield and lower burst. Although we find reductions in burst and yield and increases in the alkali consumption sheet density and foaming tendency this may not warrant the capital expenditure for extra equipment required to do the cleaning and separation. The foam problem was alleviated somewhat by addition of deformer prior to fibrilazation. Beter washing techniques both prior and post fibrilazation could help in this problem. There may be some increases in the fuel value of the black liquor that warrants pulping the pith, etc. with the woody material. One way or another, the pith is not introduced into the sheet where it does more harm than good. The fuel value is either reclaimed in a recovery boiler or waste fuel boiler.

TABLE V

	ALKALI CONSUMPTION	BURST	TEAR	DENSITY	FOAM
PULP TRIAL I	87.97	17.0	3.2	.412	Moderate
PULP TRIAL III	98.85	15.0	4.48	.442	High

Although this study did not cover every aspect of this topic, the important initial questions were answered. From the samples included in Appendix A, we find the fiber does make a good handsheet although somewhat lacking in strength. This was to be expected when the mean woody fiber length is only 0.51 mm. It would not be used to impart strength to a sheet, but could have other uses such as softness, bulk, or as a filler. In comparing the handsheets we find that the larger chips gave an increase in shive while decreasing the chip size resulted in a reduction in the number and size of the shives. The handsheets produced from the pulp made with chips, pith, fine, etc. were consistently lighter in color and seemed to have less shives than the others.

The pith can be successfully removed from the woody fiber along with the outer layer by mechanical means in a water dispersion. Separating the pith outer layer and woody fiber can also be done. The outer layer is easily removed by a vibrating screen because of its size and density (heavier than water). The pith can be separated by hand, but this is not practical on a very large scale and was a result of the lack of appropriate equipment. However, there is equipment that exists, i.e. pressure screens that can be fitted with 1/8" or 1/6" holes that would pass the pith, outer layer, and fines and keep the woody fraction for use as the accepts. The rejects could then be processed for waste fuel.

CONCLUSIONS

Jerusalem Artichokes are a fast growing , renewable source of fiber that is grown with a minimal amount of effort under the poorest conditions. They hold potential in two areas.

The stalk contains material that can be used as a source of papermaking fiber. At a 7% consistency, the stalk can be broken down by mechanical action into a woody fraction, pith, and fines (includes outer skin). When the woody material is pulped in a soda cook a 68-75% yield can be achieved. When the woody fraction is not separated from the pith and outer skin, the yield is greatly reduced along with an increase in hydroxide consumption. The separated pith and outer skin can be used as a waste fuel to recover the potential energy. Foam is definitely a problem to be reckoned with.

The tuber that the plant develops can be processed and converted into alcohol. The potential from an acre of Helianithus Tuberosus is nearly five times that of corn.

Jerusalem Artichokes can provide both energy and fiber for the future.

RECOMMENDATIONS

From the work I have completed, I would recommend the following:

1. Development of an effective and economical method for separating the pith and the woody fiber.

2. Development of a pulping method which results in the highest yield.

3. Determination of the economics of optimal pulping methods versus the increase in capital investments.

4. Determination of the econimcs of Jerusalem Artichokes as a pulp source versus its use as a waste fuel or fodder for cattle.

5. Development of a bleaching sequence which results in the highest economical brightness.

6. To extend the knowledge gained from work on Jerusalem Artichokes and apply it to other members of the Helianthus family currently in agricultural production.

FOOTNOTES

[1]Gleason, Henry A., "Illustrated Flora of the Northeastern United States and Adjacent Canada, Vol. 3", Hafner Publishing Co., Inc., New York, p. 337.

[2]Casey, J. P., "Pulp and Paper Vol. I", Interscience Publishers, New York, 1952, p. 244-246.

[3]Mukherjea, V. N.; and Guha, S. R. D., "High Yield Pulps by Hot Caustic Soda Process", <u>Indian Pulp and Paper,</u> Aug. 1965, Vol. 20, No. 2.

[4]"Non-Wood Plant Fiber Pulping Progress Report, No. 4", CA Report No. 53, 1973.

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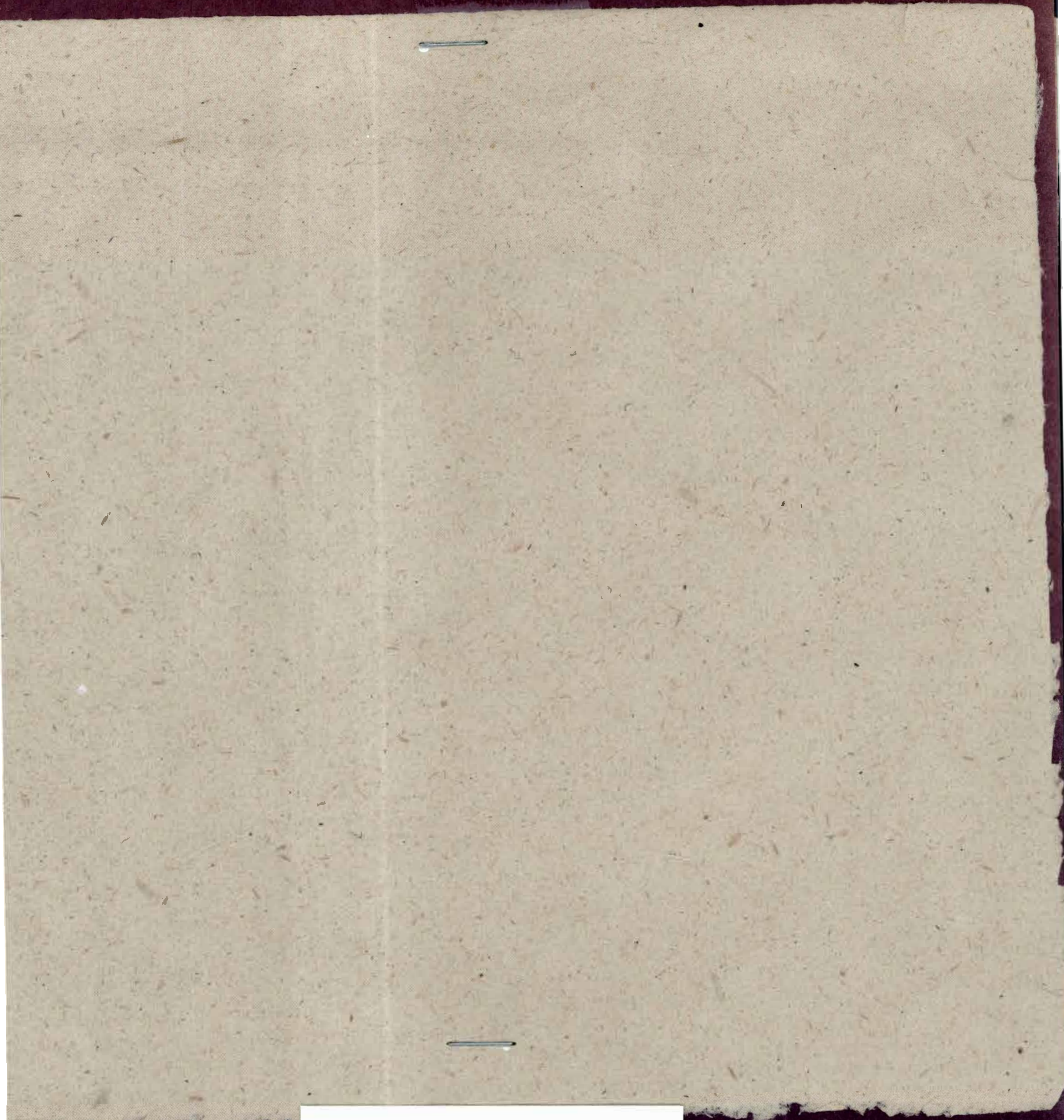
FINES MATERIAL REJECTED
THROUGH VIBRATING SCREEN



PULP TRIAL I

PULP TRIAL II

PULP TRIAL III