Quantitative Comparison Between Carborundum Stones and Resinoid Disks in Dehulling Cereal Grains

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ABSTRACT

Three dehullers, one with coarse-grit Carborundum stones, one with fine-grit Carborundum stones, and one with medium-grit resinoid disks, were quantitatively compared using barley and sorghum as test grains. Power consumption, abrasion rates, and flour color were measured at various speeds and times, and these factors were used to calculate throughputs and extraction rates. The resinoid disks and fine-grit stones gave a more selective removal of the outer layers of the kernels than did the coarse-grit stones and hence a higher extraction rate with an acceptable flour color. Abrasion rates with the resinoid disks and fine-grit stones were lower than with the coarse-grit stones, but this was more than offset by the higher extraction rate in the determination of throughput.

Reichert and Youngs (1976) have described a modification of the Hill grain thresher (HGT) that adapts it for the dehulling and pearling of grains. This unit consists essentially of a number of Carborundum stones rotated on a horizontal shaft inside a rubber-lined case. The grain is fed from a hopper into one end of the case and withdrawn from the other end through an overflow outlet. A fan aspirates the fines from the case to a cyclone collector.

The HGT has been evaluated for the pearling of sorghum and millet (Reichert and Youngs 1976), cowpeas (Reichert et al 1979), and mung beans (Del Rosario 1975). It has also been field tested in pilot mills for sorghum, maize, millet, and cowpeas in Nigeria, Botswana, Senegal, Ghana, and Sudan (Eastman 1980). As a result of this testing, further modifications have been made. In one version, the Carborundum stones were replaced by resinoid disks, and, in another, the unit was modified so that small batches of grain could be processed.

In this article, the original and two modified versions of the HGT are compared in terms of abrasion rate, flour color, flour ash, protein content of fines, throughput, and power requirements. Two grains, barley and sorghum, were used. Barley was selected because of its availability and the wide variation in fractions obtained on progressive pearling (Normand et al 1965, Pomeranz et al 1971, Robbins and Pomeranz 1972). Sorghum was used because of its importance as a staple cereal in the countries where the pilot mills are operated.

MATERIALS AND METHODS

Barley (cv. Betzes) obtained from Early Seed and Feed Ltd., Saskatoon, Saskatchewan, and grain sorghum (U.S. Yellow No. 2) obtained from Terminal Grain Corp., Sioux City, IA, were dehulled at moisture levels of 7.4 and 7.0%, respectively. A brief
description of each dehuller and the manner in which it was operated to obtain various extraction levels follows.

**HGT**

The HGT (14 × 30 in.) contains 13 Carborundum stones 12 in. in diameter (Fig. 1A). They are K-face grinding wheels, 1.25 in. thick, made of extra coarse grit silicon carbide abrasives (85% of the total composition) with vitrified clay bonds and are manufactured by Bay State Abrasives, Brantford, Ontario. The case was lined with ¼ in. thick rubber matting.

In the present experiments, the HGT was operated on a batch basis, without the use of air aspiration while dehulling, as described by Reichert and Youngs (1976). Fifty pounds of grain was loaded into the machine and the stones rotated for 1 min at 1,300 rpm for sorghum and barley and also at 1,700 for the latter. The grain was then released and passed through an air separator to remove the fines. The dehulled grain was sampled and reintroduced into the HGT for another increment of time. This procedure was repeated a number of times to produce cumulative extraction levels of approximately 65%. Throughputs were calculated in pounds per hour on the basis of the retention time and the initial load in the machine.

**Resinoid Disk Dehuller**

The resinoid disk dehuller (RDD), designed in the Prairie Research Laboratory (PRL), contains 27 resinoid steel cut-off disks, 12 in. in diameter and ½ in. thick, in a 14 × 36-in. case (Fig. 1B). The resinoid disks are made up of medium-grit aluminum oxide abrasive (67%), cured phenol formaldehyde resin bond (14%), and Fluorspar (10.6%) and are reinforced with fiberglass (7%) to improve their strength. They were supplied by Samuel Osborn Canada Ltd., Brampton, Ontario, on special order. Two disks (one at each end of the machine) are angled at 9° to the vertical by aluminum wedge spacers to avoid dead spaces at the ends of the case. The remaining 25 disks are separated by aluminum spacers 1-in. thick. The case in this unit was unlined. The RDD was operated in the same way as the HGT except that 70 pounds of grain was used for each experiment and the disks were rotated at 1,300, 1,700, and 2,000 rpm. Eastman (1980), who refers to this machine as the PRL dehuller, describes it in detail and explains the systems set up for its use in Africa.

**Rural Industries Innovation Center Dehuller**

The original HGT was modified at the Rural Industries Innovation Center (RIIC) in Botswana, to process small quantities of grain. The advantages of the RIIC dehuller have been described by Eastman (1980), who refers to it as the PRL/RIIC dehuller. The RIIC dehuller (11 × 25 in.) contains 13 Carborundum stones 10 in. in diameter and ¼ in. thick (Fig. 1C). They are similar in composition to the stones in the HGT except that they are fine-grit stones manufactured by Norton Company of Canada Ltd., Hamilton, Ontario.

The RIIC dehuller was first operated without a liner; a rubber liner ¾ in. thick was then installed on the inside of the box. It was run at 1,300 and 2,000 rpm. Thirty-five pounds of grain was used as the initial load.

**Flour Reflectance Measurements**

Whole and dehulled grain samples were ground in a Udy Cyclotec grinding mill (1-mm screen) and the flour obtained was thoroughly mixed. Reflectance of flour-water slurries was measured on an Agtron M-500A using the blue mode (436 nm). The reflectance spectrophotometer was standardized at 0 and 100% transmittance, using the 00 and 90 color standards supplied with the machine. Flour-water slurries were prepared according to the method of Oomah et al. (1981). Two grams of flour were weighed into the Agtron sample cup, and distilled water (6 ml for barley and 3 ml for sorghum) was added to give a thin slurry. The slurry was well mixed and allowed to stand for a few minutes before readings were taken.

**Proximate Analyses**

Total nitrogen of the fine fractions obtained after dehulling was determined by the AACC method (1969). Protein was calculated as N × 6.25 and expressed on a moisture free basis.

Ash content of the grain samples was determined by the AACC method (1969).

**Power Consumption**

The dehullers were powered by 550-volt, three-phase electric induction motors, 10 hp for the HGT and RIIC dehullers and 15 hp for the RDD dehuller. Power consumption was measured by

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**Fig. 1.** Top view of the interior of three dehullers, illustrating Carborundum stones or resinoid disks: A, Hill grain thresher; B, resinoid disk dehuller; and C, Rural Industries Innovation Center dehuller.

**Fig. 2.** Retention time of barley vs percent kernel removed. Hill grain thresher: □, 1,300 rpm; ■, 1,700 rpm; and resinoid disk dehuller: ●, 1,300 rpm; ○, 1,700 rpm; Δ, 2,000 rpm.
ameters (Kyoritsu KM-86) on each of the three phases, with the mean of the three readings used in the calculation of power requirements.

RESULTS AND DISCUSSION

The rate of abrasion of barley kernels in the HGT and RDD at various rotational speeds is shown in Fig. 2. As expected, the abrasion rate increases with increasing speed in both units, and the percent kernel removed at a given time is proportional to the speed for each unit. At the same speed, the HGT with its extra coarse grit stones abraded the kernels at about twice the rate of the RDD with its smoother resinoid disks, in spite of the fact that the RDD contained 27 disks and the HGT only 13 stones.

Because the stones are more abrasive than the disks, they remove more of the kernel at each contact and therefore are less selective in removing the outer layer of the kernel. This is demonstrated by the plot of flour color vs percent kernel removed (Fig. 3). For either the HGT or the RDD, rotational speed had little effect, but a very significant difference was found between the HGT and the RDD at all speeds. The flour color lightened more rapidly with the RDD as a result of the more selective removal of the more highly pigmented outer layers of the kernel. The more selective action of the RDD is also illustrated in Fig. 4 in the graph of ash content vs percent kernel removed. Again, effect of speed was small for the HGT or the RDD, but the RDD caused a more rapid drop in ash content. The ash content was inversely related to flour reflectance.

The protein content of the fines abraded from the kernels provides a more sensitive measure of the selectivity of the abrasive equipment (Fig. 5). The RDD gave lower initial protein levels and higher subsequent values than the HGT, which gave a flatter curve. This is a result of the RDD’s greater selectivity in first removing the low protein hull layer and then the high protein aleurone layer. Differences due to rotational speed are apparent, the lower speeds being more selective in both units. The highest protein levels were obtained at 16–24% kernel removal, as previously noted by Normand et al. (1965). The distribution of the protein in the kernel is very different from that of the ash, as has been observed by Pomeranz et al. (1971).

The more selective action of the RDD gave a higher extraction rate for a given flour color. Table 1 shows barley extraction rates, throughput, and power requirements for the HGT and RDD at an arbitrarily selected flour reflectance of 42. The 12% higher flour yield with the RDD is highly significant. Because less of the kernel had to be removed to reach a specified color and because of the higher capacity (initial load) of the RDD, throughputs for this unit were higher than for the HGT operated at the same speed. The power requirements, expressed as horsepower per 1,000 lb of

**TABLE 1**

<table>
<thead>
<tr>
<th>Dehuller</th>
<th>Stone Speed (rpm)</th>
<th>Throughput (lb/hr)</th>
<th>Power Requirement (hp-hr/1,000 lb)</th>
<th>Extraction Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill grain thresher</td>
<td>1,300</td>
<td>345</td>
<td>17.4</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>1,700</td>
<td>612</td>
<td>14.3</td>
<td>64</td>
</tr>
<tr>
<td>Resinoid disk thresher</td>
<td>1,300</td>
<td>411</td>
<td>14.5</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>1,700</td>
<td>677</td>
<td>11.2</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>2,000</td>
<td>857</td>
<td>10.0</td>
<td>76</td>
</tr>
</tbody>
</table>

*A reflectance of 42 at 436 nm.
grain, were lower for the RDD than for the HGT. Power requirements also decreased with increasing speed, so that, under the conditions tested, the RDD at 2,000 rpm was the most effective of the units in terms of extraction rate, throughput, and power use.

The results for dehulling sorghum with the HGT and RDD were similar to those for barley (Figs. 6 and 7). The HGT abraded the kernels more rapidly but was less selective than the RDD in removing the outer colored layers. At 1,300 rpm, the RIIC dehuller was slower to abrade the kernels than the RDD, but the installation of a rubber liner in the RIIC unit brought the abrasion rate closer to that of the RDD. With the slower abrasion rate, the RIIC dehuller gave a slightly more selective removal of the colored layers than the RDD did. At 2,000 rpm, the RIIC dehuller without a liner gave an abrasion rate equivalent to that of the RDD. With the rubber liner, the abrasion rates of the RIIC unit were higher. The selectivity of the RDD was intermediate between those of the RIIC dehuller with and without the liner.

Table II shows sorghum extraction rates, throughput, and power requirements for the HGT, the RDD, and the RIIC dehuller with and without a liner at a flour reflectance value of 22. As it did for barley, the RDD gave a higher extraction rate, higher throughput, and lower power requirement than the HGT at 1,300 rpm. The RIIC at 1,300 rpm gave extraction rates similar to those of the RDD. The liner had little effect on the extraction rate, but the inclusion of the liner increased the throughput because of the higher abrasion rate. Because of its smaller capacity, the throughputs of the RIIC dehuller were lower than those of the HGT and RDD. The power requirement of the RIIC was slightly higher than that of the HGT. At 2,000 rpm, the extraction rate was highest for the RIIC without the liner, followed by the RDD, and then the RIIC with the liner. At this higher speed, the rubber liner in the RIIC appeared to inhibit the free movement of the kernels, with the result that those in contact with the stones were unduly abraded and the outer layers less selectively removed. The lower extraction also resulted in a lower throughput with the liner in spite of a somewhat higher abrasion rate. The RDD gave higher throughputs than the RIIC with or without the liner, but the RIIC without the liner gave acceptable throughput with good extraction rates and low power consumption.

In conclusion, both barley and sorghum, the fine-grit stones or resinoid disks were a definite improvement over the coarse-grit stones for selective removal of the outer layers of the kernel and therefore for extraction rate. They are recommended in any future units. The resinoid disks have additional advantages of being much less expensive, much lighter in weight, and not subject to possible cracking and subsequent disintegration during operation.

**TABLE II**

*Power Consumption, Throughput, and Extraction Rate for a Given Flour Color* of Sorghum

<table>
<thead>
<tr>
<th>Dehuller</th>
<th>Stone Speed (rpm)</th>
<th>Throughput (lb/hr)</th>
<th>Power Requirement (hp-hr/1,000 lb)</th>
<th>Extraction Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill grain thrasher</td>
<td>1,300</td>
<td>2,070</td>
<td>3.6</td>
<td>72</td>
</tr>
<tr>
<td>Resinoid disk dehuller</td>
<td>1,300</td>
<td>2,580</td>
<td>2.8</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>2,000</td>
<td>4,740</td>
<td>1.9</td>
<td>85</td>
</tr>
<tr>
<td>Rural Industries Innovation Center dehuller</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without liner</td>
<td>1,300</td>
<td>1,140</td>
<td>3.3</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>2,000</td>
<td>2,800</td>
<td>2.0</td>
<td>87</td>
</tr>
<tr>
<td>With liner</td>
<td>1,300</td>
<td>1,400</td>
<td>3.9</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>2,000</td>
<td>2,330</td>
<td>2.8</td>
<td>80</td>
</tr>
</tbody>
</table>

* A reflectance of 22 at 436 nm.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


POMERANZ, Y., KE, H., and WARD, A. B. 1971. Composition and
Structural Characterization of Legume Starches. I. Studies on Amylose, Amylopectin, and Beta-Limit Dextrins

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ABSTRACT

The application of electron microscopy to the structural analysis of legume starches is described. It is shown that the fine structure of these starches is similar to that of cereal starches. The starch granules of the legume starches are spherical and the amylopectin component is arranged in helical or parallel manner, thus forming a gel-like matrix. The amylose component, on the other hand, is present in the form of intergranular and intragranular amyllopectin. The length and breadth of the granules of legume starches are comparable with those of cereal starches. The present study provides a basis for further investigations on the structure and function of legume starches.

INTRODUCTION

This investigation was attempted to determine the structural characteristics of the components of legume starches. The attempt was also made to relate these characteristics to nutritional properties of the starch granules.

MATERIALS AND METHODS

Starch Isolation

The following legume starches were prepared from their seeds by a wet-milling process (Biladeris et al., 1979): amaranth pea (Crotalaria juncea L.), field pea (Pisum sativum L.), yellow pea (Pisum sativum L.), and fenugreek (Trigonella foenum-graecum L.).

Analytical Methods

The analytical methods were used for the determination of degree of polymerization, amylose content, and leaching viscosity numbers. The leaching viscosity numbers of the legume starches were determined using a modified Leaching Viscosity method (1979). The degree of polymerization of the legume starches was determined as described previously (Biladeris et al., 1979).

RESULTS AND DISCUSSION

The results obtained are summarized in Table I. The leaching viscosity numbers of the legume starches were found to be in the order of 10,000, which is comparable with those of cereal starches. The degree of polymerization of the legume starches was found to be in the range of 200-300, which is comparable with those of cereal starches.

CONCLUSIONS

The present study provides a basis for further investigations on the structure and function of legume starches. The results obtained are comparable with those of cereal starches, which indicates that the legume starches are similar in structure to cereal starches. The legume starches are also similar in nutritional properties to cereal starches. The present study also provides a basis for further investigations on the nutritional properties of legume starches.

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