Laboratory Abrasive Decorticating Mill for Small Grains

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ABSTRACT

Modifications are described for conversion of a grinding chamber and cyclone collector of a Udy cyclone sample mill to a laboratory decorticating mill. Batch size may be varied in the approximate range of 5–25 g. Operation on wheat and on long, medium, and short grain rice is simple, but grain sorghum requires special procedures.

Samples of 5–25 g of small grains are useful for testing by breeders and others restricted by the quantity of grain available, but few (Barber 1972, Hogan et al 1964, Scott et al 1964) have described laboratory decorticating mills for small samples of small grains. The mills described are deficient in the convenience of collecting bran and decorticated grain and/or in the ease and speed of operation.

The mills described by Hogan et al (1964) and Barber (1972) are similar in principle. A column of grain is placed in an open tube positioned to just clear a rotating horizontal abrasive disk. The grain circulates well within the mass, which tends to produce uniform abrasion. However, the fines abraded are centrifuged into a receiver and recovery of them and removal of the abraded grain from the tube are inconvenient. Furthermore, 30 min to 1 hr may be required to remove 2–5% fines.

In the mill described by Scott et al (1964), samples of up to 15 g of brown rice are mixed with an equal weight of aluminum oxide abrasive and shaken in test tubes. Untreated rice requires 45 min and parboiled rice 60–90 min. However, 80 samples of less than 5 g or 48 samples of 5–15 g may be run simultaneously. Separating "pure" fines from the abrasive is difficult.

Decortication equipment with greater capacity is available (Barley Pearlers, McGill No. 1 and 2 Rice Miller, and Satake Grain Testing Mill), but they do not handle smaller samples. This article describes the development and operation of a mill that meets this need.

MATERIALS AND METHODS

Wheat

A hard red spring wheat was hand picked to remove broken and otherwise damaged kernels. The sample had been previously selected for uniformity of size.

Rice

All types were handpicked to remove paddy grains, hulls, and damaged and broken kernels. Long grain was Bluebonnet variety; medium grain, Calrose; and short grain, Pearl.

Sorghum

Funk G-766W variety was cleaned and sized in a dockage tester. The material passing a No. 31 screen (10/64 in. round perforation-dimpled) and retained on a No. 10 screen (8/64 in. round perforation) was further handpicked to remove grain with glumes or broken and damaged kernels. It was again shaken over a 9×9 in. screen with 8/64 in. round perforations to remove a few undersized kernels not removed in the dockage tester.

RESULTS AND DISCUSSION

We developed a decorticating mill for use in the laboratory on 5–25 g batches of grain. It provides convenient quantitative (about 99%) recovery of fines and abraded grain, and machine components and operating variables can be selected to adjust milling rate and degree of decortication.

Description

Chamber. The basic unit is a milling chamber of the Udy cyclone sample mill; the chamber has an opening that allows discharge through a perforated plate to a cyclone collector. The modification and an array of interchangeable parts are shown in Fig. 1.

Cover. The transparent plastic cover has a central feed funnel, a slot for removing the perforated plate that covers the discharge to the cyclone, and a connection for an air-suction hose that provides air-flow for the cyclone (Figs. 1 and 2). The transparent cover allows the operator to view the action (which can be enhanced with strobe lighting) or to photograph or video tape it, or even to film it with a high-speed movie camera.

Drive. The drive is provided by a 0.5 HP, adjustable-speed (0–2,400 rpm), reversible motor and speed control (Fig. 2). This unit provides substantially constant torque over the entire range of speed.

Impeller. The impeller design was developed to minimize breakage of grain (Fig. 1). Clearances with chamber parts (side walls, cover, and bottom) must be either very small or well over the largest dimension of the grain. Clearance dimensions near those of

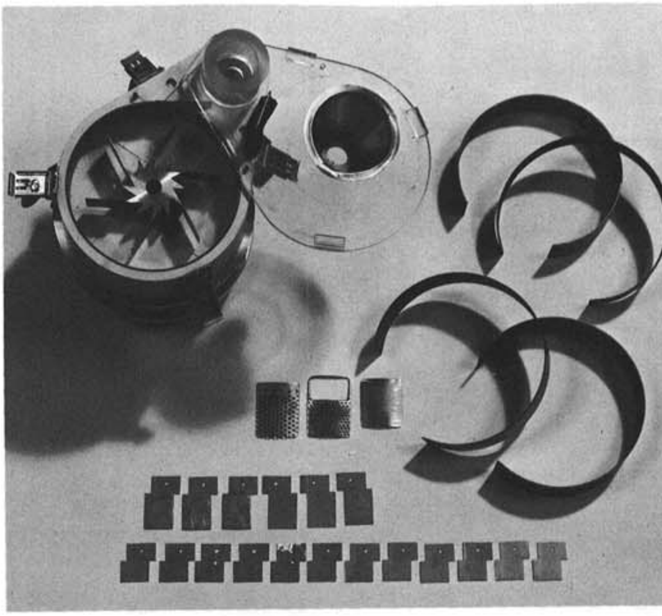

Fig. 1. Partially assembled grinding chamber and cyclone collector with an array of alternate machine components.

[1]Reference by the USDA to a company and/or product is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

the grains will pinch and break them. Therefore some adjustment in design may be desirable depending on the size of grain to be milled. Our design has been generally useful. It has a hub machined with twelve 60° V-grooves. One side of the V is radial; the other side is 60° clockwise. Rigid blades are screwed to the nonradial face. When used with counterclockwise rotation, the blade is inclined backward. The distance across the blades is 4 1/4 in. The ID of the chamber is 5 1/4 in. The impeller can be used with three, four, six, or 12 blades, and the length of the blade may be altered.

Abrasive. An abrasive surface covers the cylindrical chamber wall except where it is interrupted for a perforated plate. The abrasive surface may be changed by using several interchangeable units (Fig. 1). The original plate from Udy is 46 grit, but others of 80, 150, and 240 grit may be used. All are made from tungsten carbide particulate brazed to steel rings.

Perforated plate. A perforated plate, located at the discharge from the grinding chamber into the cyclone separator, may be selected for hole size to limit the particle size passing to the collector during milling. For most cereal grains, the plate with 1-mm round perforations furnished by Udy seems to be satisfactory. Sorghum requires a plate with much larger openings, however, because the flakes produced during decorticating are large.

Air Suction System. The amount of suction, which we applied from a vacuum cleaner, may require adjusting. Opening the bypass (Fig. 2) may not sufficiently reduce the suction. To further reduce flow, a test-tube brush that fits tightly into the hose may be put into the bypass opening. The ring on the end of the wire handle stops the brush from being drawn down the hose.

Operation

After selection of an abrasive surface, impeller, and perforated plate, the impeller is started by moving the three-position switch (forward, brake, reverse) of the speed control (Fig. 2) to "forward".

Fig. 2. Laboratory decorticating mill with drive and speed controller.

The speed is adjusted with the dial and indicated on the meter. ("Forward" is counterclockwise, a feature preserved from Udy operation, which is designed to require an abrupt change in the direction of the air as it exits the chamber into the cyclone.) The vacuum cleaner is turned on and, with the receiver in place, the batch of grain is introduced quickly through the central funnel. After any selected time period, the action is stopped by turning the motor control to the brake position. The vacuum cleaner is turned off and the first receiver (now containing the material abraded from the surface) is removed and replaced. The remaining grain sample is collected in the second receiver by lifting the perforated plate at the entry to the cyclone, turning on the vacuum cleaner, and moving the motor control to "reverse" for a few seconds. In reverse, the discharge of the decorticated grain into the cyclone is straight.

The net weight in the two receivers can be used to check recovery, which is typically around 99% for batches of 5–25 g, and to calculate the degree of decortication quickly. Some typical results are presented in Table I.

Hard red spring wheat is somewhat more resistant than the rices to abrasion. At 1,500 rpm with the 240 grit, only 7.1% of the grain was removed in 120 sec, whereas about 10% decortication of the brown rices, enough for a "well-milled" rice, required 90–100 sec.

The effects of grit and of impeller speed are shown in Table I for long grain rice. At 2,400 rpm with 150 grit, less than 15 sec was required for 10% removal, whereas at the same speed with 240 grit, about the same amount was removed in 20 sec. In contrast, 40 sec at 1,800 rpm or 90 sec at 1,500 rpm were required to achieve the same degree of milling.

The effect of load (10–25 g) on short grain rice is shown in Table I. There was no great difference for batches of 10, 15, or 20 g. For a 25-g batch, however, the amount of decortication dropped substantially. The agreement between duplicates is shown for 10-g batches of short and medium grain rices.

Wheat, rice, and most other grains decorticate to remove a fine material that easily passes a 1-mm round perforated plate. Sorghum, however, decorticates in quite large flakes, and very little of the material removed will pass a 1-mm round hole without further attrition. The material therefore accumulates in the chamber, and the ease of separating and weighing is not the same for sorghum as for the other grains. The abraded material and the decorticated grain can be separated by screening and aspiration,

TABLE I

Mill[a] Performance on Wheat and on Long, Medium, and Short Grain Rice

	Grit	Speed (rpm)	Time (sec)	Sample Size (g)	Decortication (%)
Hard red spring wheat	240	1500	15	10	1.2
			30		2.1
			45		2.8
			15		4.3
			120		7.1
Long grain brown rice	150	2400	15	10	11.5
	240		15		7.7
			20		11.7
		1800	30		7.8
			40		9.6
		1500	60		7.9
			75		9.1
			90		9.9[b]
Medium grain brown rice	240	1500	75	10	7.4
			105		10.6
			105		11.1
Short grain brown rice	240	1500	105	10	9.9
			105	15	10.2
			105	20	10.0
			105	25	8.2
			105	10	9.3

[a]A 4 1/4-in. six-blade impeller with a 1-mm round perforated plate was used.

[b]78.5% head and 11.6% brokens.

but that is an involved process requiring other equipment and handling, so we tried to find a perforation size that would allow for simple separation at the mill.

Funk G-766W grain sorghum was sieved, and overs from an 8/64-in. round perforated sieve were used. Therefore, a 7/64-in. round perforation was chosen as the largest that could be useful. The performance of the mill was checked for several screens, and the results are shown in Tables II and III. For each screen, the abraded material was collected in receiver 1. The contents of receiver 2 were separated on a 20-mesh US standard screen. The throughs (−) were added to receiver 1. The overs (+) were further separated in a seed blower and the light fraction, the flakes, added mathematically to receiver 1. The sum of these three is the decorticate (surface material removed from the grain) shown in column 6 of Table II.

This sum (column 6) for the 7/64-in. sample was high because the contents of its receiver 1 contained some broken grain. A seed blower operating on the +20 screened material separated a 0.75-g heavy fraction, and 0.75 g was used to adjust columns 1, 5, and 6 in Table II. With the adjustments (in parentheses in Table II), the figures for the 7/64 in. sample become consistent with those for the other samples.

Of the perforations tested, the 3/32-in. round perforated plate provided the most satisfactory separation (Table II). Of the 2.2 g of decorticate, 2.13 g were recovered at the mill, which represents about a 5% loss. For many purposes this may be satisfactory.

The performance was further checked by estimating damage to the milled grain (Table III). This was done visually with some assistance by screening. The material obtained using the 3/32 in. plate was not damaged as much as that from the 7/64 in. plate.

The amount of decortication is a useful measure, but additional information such as the amount of damage to the decorticated grain and the uniformity of decortication is desirable to evaluate the machine performance more fully. Means are being devised to speed the estimate of damage by using a screening followed by an inspection, and a dyeing technique is being investigated as a possible way to estimate degree of uniformity.

This article has reported the performance and general usefulness of the laboratory decorticating mill on a range of grain types. The mill has considerable versatility because of the numerous machine and operating variables. Influence of these on degree of decortication, breakage, and uniformity must be determined for each grain type so that adjustments can be made to optimize performance. This effort will be reported.

TABLE II
Influence of Hole Size of Perforated Plate on Mill Performance[a] on 20 g Batches of Grain Sorghum

Size of Round Perforations (in.)	Receivers (g) 1	Receivers (g) 2	Fractionation of Receiver 2 (g) −20 Mesh	+20 Light	+20 Heavy	Decorticate $\Sigma(1)+(3)+(4)$[b]
1/32 in.	1.15	18.71	0.53	0.54	17.50	2.22
1 mm	0.89	19.05	0.53	0.63	17.71	2.05
1/16 in.	1.69	18.35	0.05	0.30	17.80	2.04
3/32 in.	2.13	17.88	0.02	0.09	17.64	2.24
7/64 in.	2.96[c] (2.21)	17.06	0.02	0.02	16.81 (17.56)	3.00 (2.25)
Column number	(1)	(2)	(3)	(4)	(5)	(6)

[a] 12-blade, 4 1/4 in. impeller, 240 grit, 1,500 rpm, 120 sec.
[b] Column number.
[c] Includes 0.75 g of broken grain. Adjusted figures are in parentheses.

TABLE III
Influence of Hole Size of Perforated Plate on Breakage of Grain Sorghum[a]

Size of Round Perforations (in.)	Fractionation of +20 Mesh Heavy (g) Whole	Degermed	Broken
1/32 in.	15.40	1.39	0.71
1 mm	15.61	1.37	0.58
1/16 in.	15.72	1.17	0.68
3/32 in.	16.08	1.14	0.42
7/64 in.	14.60	1.96	0.25 (1.00)[b]

[a] 12-blade, 4 1/4-in. impeller, 240 grit, 1,500 rpm, 120 sec, 20-g batches of grain sorghum.
[b] Includes 0.75 g of broken grain. Adjusted figure is in parentheses.

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