Quantitative Comparison Between Carborundum Stones and Resinoid Disks in Dehulling Cereal Grains[1]

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ABSTRACT

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Three dehullers, one with coarse-grit Carborundum stones, one with fine-grit Carborundum stones, and one with medium-grit resinoid disks, were quantitively 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 The grain is fed from a hopper into one end of the case and withdrawn from the other end through an overflow outlet.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[3]). 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

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[3] R. R. Del Rosario, A. C. Bote, S. M. Rubico, and D. M. Flores. Studies on the dehulling of mungbean *Vigna radiata* (L.) Wilczek. Paper presented at the IDRC Legume Seminar, Singapore, December 3–4, 1979.

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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 ¼ 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 ¾ 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 ⅛ 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 Cyclo-Tec 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

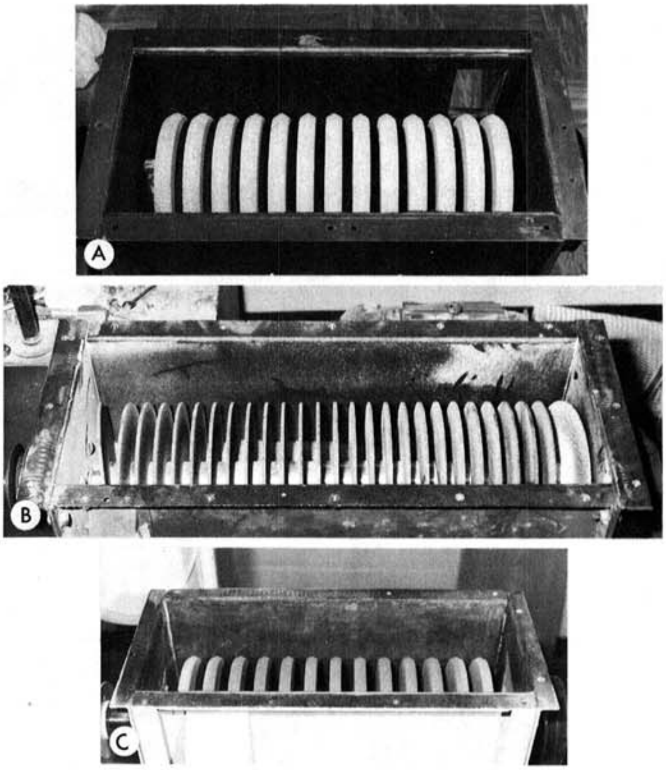

Fig. 1. Top view of the interior of three dehullers, illustrating Carborundum stones or resinoid disks: **A,** Hill grain thresher; **B,** resinoid disk dehuller; and **C,** Rural Industries Innovation Center dehuller.

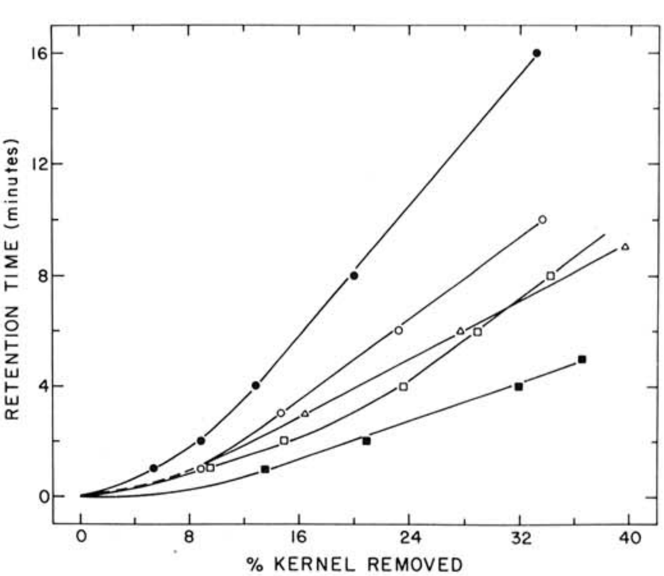

Fig. 2. Retention time of barley vs percent kernel removed. Hill grain thresher: □, 1,300 rpm; ■, 1,700 rpm; and resinoid disk dehuller: •, 1,300 rpm; o, 1,700 rpm; Δ, 2,000 rpm.

ammeters (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 I 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 hours per 1,000 lb of

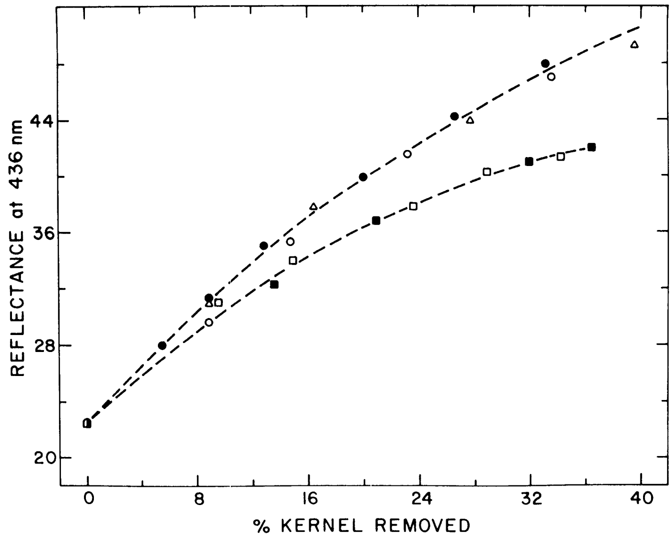

Fig. 3. Effect of dehulling on barley flour reflectance (436 nm). Hill grain thresher: □, 1,300 rpm; ■, 1,700 rpm; and resinoid disk dehuller: •, 1,300 rpm; o, 1,700 rpm; Δ, 2,000 rpm.

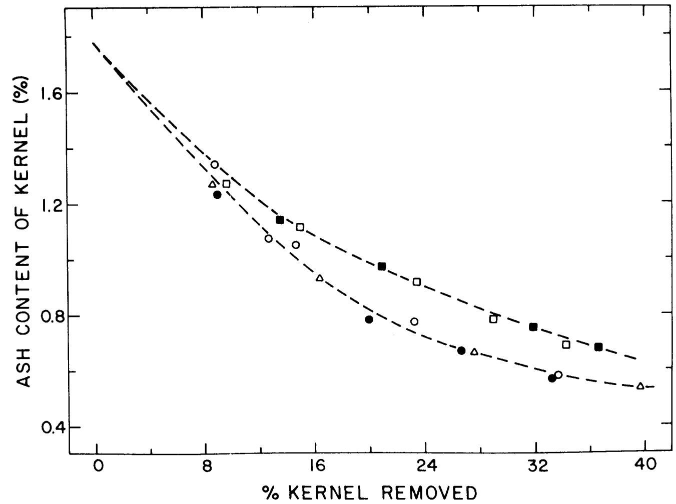

Fig. 4. Effect of dehulling barley on its ash content. Hill grain thresher: □, 1,300 rpm; ■, 1,700 rpm; and resinoid disk dehuller: •, 1,300 rpm; o, 1,700 rpm; Δ, 2,000 rpm.

TABLE I
Power Consumption, Throughput, and Extraction Rate for a Given Flour Color[a] of Barley

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

[a] A reflectance of 42 at 436 nm.

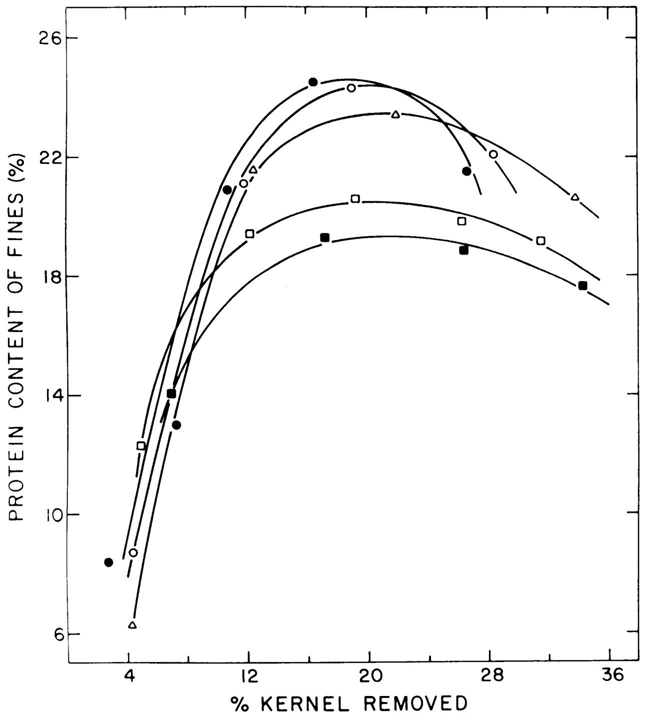

Fig. 5. Effect of dehulling barley on the protein content of the fine fraction. Hill grain thresher: □, 1,300 rpm; ■, 1,700 rpm; and resinoid disk dehuller: •, 1,300 rpm; o, 1,700 rpm; Δ, 2,000 rpm.

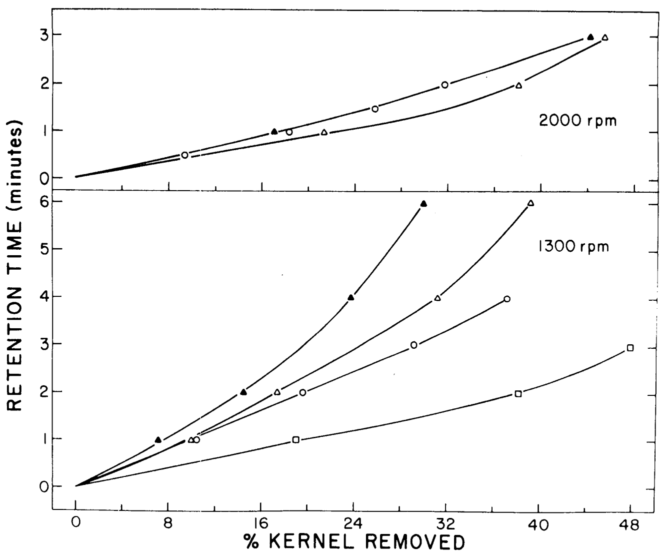

Fig. 6. Retention time of sorghum vs percent kernel removed at 1,300 rpm and 2,000 rpm. □, Hill grain thresher; o, resinoid disk dehuller; ▲, Rural Industries Innovation Center (RIIC) dehuller; Δ, RIIC dehuller with the liner.

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. Along 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, for 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.

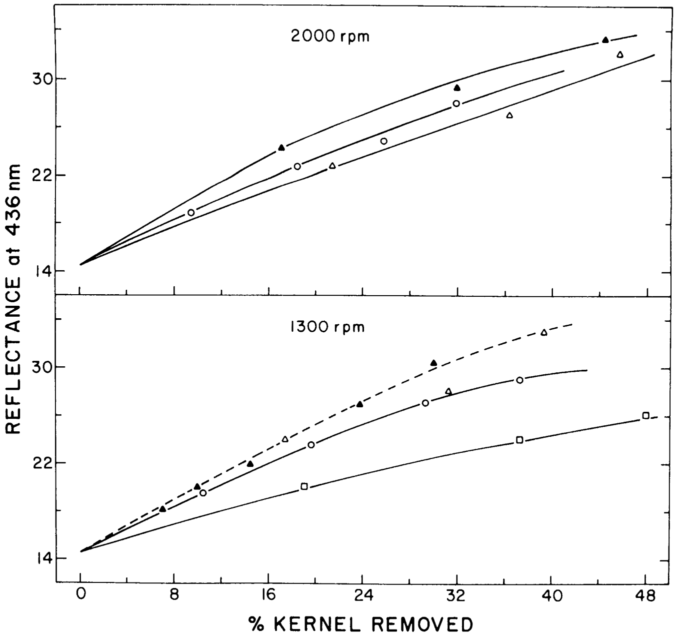

Fig. 7. Effect of dehulling on sorghum flour reflectance at 1,300 rpm and 2,000 rpm. □, Hill grain thresher; o, resinoid disk dehuller; ▲, Rural Industries Innovation Center (RIIC) dehuller; Δ, RIIC dehuller with the liner.

TABLE II
Power Consumption, Throughput, and Extraction Rate for a Given Flour Color[a] of Sorghum

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

[a] A reflectance of 22 at 436 nm.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1969. Approved Methods of the AACC. Method 46-08, approved April 1961, and Method 08-01, approved October 1976. The Association: St. Paul, MN.

EASTMAN, P. 1980. An end to pounding: A new mechanical flour milling system in use in Africa. IDRC-152e. International Development Research Center: Ottawa, Canada. 63 pp.

NORMAND, F. L., HOGAN, J. T., and DEOBALD, H. J. 1965. Protein content of successive peripheral layers milled from wheat, barley, grain sorghum, and glutinous rice by tangential abrasion. Cereal Chem. 42:359.

OOMAH, B. D., REICHERT, R. D., and YOUNGS, C. G. Development and testing of a small-sample tangential abrasive dehulling device (TADD). Cereal Chem. 58:392.

POMERANZ, Y., KE, H., and WARD, A. B. 1971. Composition and utilization of milled barley products. I. Gross composition of roller-milled and air-separated fractions. Cereal Chem. 48:47.

REICHERT, R. D., LORER, E. F., and YOUNGS, C. G. 1979. Village-scale mechanical dehulling of cowpeas. Cereal Chem. 56:181.

REICHERT, R. D., and YOUNGS, C. G. 1976. Dehulling cereal grains and grain legumes for developing countries. I. Quantitative comparison between attrition- and abrasive-type mills. Cereal Chem. 53:829.

ROBBINS, G. S., and POMERANZ, Y. 1972. Composition and utilization of milled barley products. III. Amino acid composition. Cereal Chem. 49:240.

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Structural Characterization of Legume Starches. I. Studies on Amylose, Amylopectin, and Beta-Limit Dextrins[1]

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ABSTRACT

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Nine purified legume starches (from smooth and wrinkled peas; adzuki, garbanzo, mung, red kidney, navy, and faba beans; and green lentil) were fractionated into their amylose and amylopectin components. The fine structures of the isolated starch components and starch β-limit dextrins were investigated using hydrolytic enzymes (pullulanase, β-amylase, and glucoamylase) in conjunction with gel filtration chromatography (Biogel P-10). The unit-chain profiles of the debranched legume amylopectins were characterized by two overlapping distributions with average degrees of polymerization of 45–55 (II-chains) and 14–18 (III-chains). The average chain length for most of these amylopectins ranged from 20 to 26. Wrinkled pea starch contained branched polysaccharide molecules with a chain length greater than that of normal amylopectin. The limiting viscosity numbers of the legume amylose fractions ranged from 136 to 251 ml/g. The incomplete β-amylolysis of the legume amyloses (78.4–89.4%) was due to the presence of a relatively small number of α-(1⟶6) linkages in the molecule. A hypothesis was developed to explain starch gelatinization and granule rigidity based on the molecular characteristics of the branched polysaccharide fractions of these starches.

The application of enzymatic methods to the structural analysis of amylaceous polysaccharides has provided useful information regarding the fine structure of these α-D-glucans (Marshall 1974). Thus, debranching of amylopectin and glycogen, using purified pullulanase (E.C. 3.2.1.41) and isoamylase (E.C. 3.2.1.68) preparations, combined with gel filtration chromatography has led to the postulation of new models for the molecular structure of these polysaccharides (French 1972, Gunja-Smith et al 1970, Robin et al 1974). Although several cereal and tuber starches have been characterized by these techniques (Atwell et al 1980; French et al 1971; Gunja-Smith et al 1970; Hood and Mercier 1978; Ikawa et al 1978; Lii and Lineback 1977; Mercier 1973; Mercier and Whelan 1970; Robin et al 1974, 1975), no comparative studies have been made on legume starches.

This investigation was conducted to determine the structural characteristics of the components of nine purified legume starches. An attempt was also made to relate these characteristics to gelatinization properties of the starch granule.

MATERIALS AND METHODS

Starch Isolation

The following legume starches were prepared from their seeds by a wet-milling process (Biliaderis et al 1979): smooth pea (*Pisum sativum* L. cv. Trapper), wrinkled pea (*Pisum sativum* L. cv. Venus), adzuki bean (*Phaseolus chrysanthos*), garbanzo bean (*Cicer arietinum*), mung bean (*Vigna radiata*), green lentil (*Lens culinaris*), red kidney bean (*Ph. vulgaris*), navy bean (*Ph. vulgaris*), and faba bean (*Vicia faba* L. cv. Diana). The proximate analysis and other physicochemical characteristics of the purified starches were reported previously (Biliaderis et al 1979, 1980). Waxy corn and potato starch were obtained from a commercial source (A. E. Staley, Inc., Decatur, IL).

Iodine Affinity

Iodine affinities (IA) for the defatted (by hot extraction in 85% aqueous methanol for 48 hr) starches and the amylose and amylopectin fractions were determined by potentiometric titration at 30.0 ± 0.1°C (Schoch 1964). Amylose contents were calculated by assuming that pure amylose has an iodine affinity of 20.0%. The wavelength of maximum absorption (λ_{max}) of the iodine-polysaccharide complexes was determined as described previously (Biliaderis et al 1979).

Gelatinization Midpoint Temperatures

Gelatinization midpoint temperatures were determined according to Schoch and Maywald (1956). The recorded temperatures correspond to loss of birefringence by approximately 50% of the starch granules.

Limiting Viscosity Numbers of the Amyloses

Limiting viscosity numbers (η), of the amyloses dispersed in $1N$ KOH, were obtained with a modified Ubbelohde viscometer according to Greenwood's method (1964). An approximation of the average degree of polymerization ($\overline{\mathrm{dp}}$) for each amylose was calculated from the relation $\overline{\mathrm{dp}} = 7.4 \times \eta$ (Cowie and Greenwood 1957).

Fractionation of Starches

Two methods were used for starch fractionation. The first was by the dimethyl sulfoxide (DMSO)-thymol granule dispersion and selective precipitation of the amylose fraction (Banks and Greenwood 1967a) and the second by selective aqueous leaching of the glycerol-pretreated granular starches (Montgomery and Senti

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[1] National Research Council of Canada Paper 19591. Taken in part from the Ph.D. thesis of C. G. Biliaderis, University of Saskatchewan, 1980.

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