NEW METHODS OF DRY MILLING HIGH LYSINE CORN

by

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INTRODUCTION

Corn, first among the feed grains in the U. S., is of primary importance as food in LATIN AMERICA. More than 50 million metric tons of corn are eaten directly by people in the form of corn meal, tortillas, arepas (corn griddle cake), gruels or flour. Corn constitutes the main staple food for about 200 million people in the LATIN AMERICAN TROPICS and SEMI-TROPICS (1).

According to the 1970 Corn Annual Report of the Corn Refiners Association, corn is the most valuable crop in the United States. In 1969 approximately 260 million acres of corn were grown throughout the world, producing 244 million metric tons. Corn is produced in practically all parts of the world yet 45 percent of the production comes from the U. S. on 25 percent of the acreage. The U. S. corn crop in 1969 was 4,577,864,000 bushels or 96,312,000 tons and it was used as follows (2):

TABLE I

Utilization of Corn 1968-69 and Estimates for 1969-70 (3)

(in millions of bushels)

	1968-69	1969-70
Seed	13	14
Wet Process	218	225
Dry Milling	100	100
Breakfast Food	12	12
Alcohol	35	35
Export	514	625
Feed	3541	3434
Total	4433	4445

It has been known for a long time that ordinary dent corn, in common with other cereals has poor protein quality. The protein content of dent corn averages 9.0 percent. It is deficient in lysine, methionine and tryptophan but an over abundance of glutamic acid and leucine is present (4).

TABLE II

Composition of Normal and Opaque-2 Corn

	Normal Corn	Opaque-2 Corn
	%	%
Protein	8.86	11.94
Dry Matter	91.88	87.10
Amino acids;		
Aspartic acid	.61	1.16
Threonine	.32	.38
Serine	.45	.50
Glutamic acid	1.89	2.17
Proline	.88	1.00
Glycine	.36	.56
Alanine	.72	.75
Valine	.42	.57
Cystine	.14	.20
Methionine	.15	.16
Isoleucine	.31	.37
Leucine	1.10	.97
Tyrosine	.39	.45
Phenylalanine	.45	.51
Lysine	.24	.49
Histidine	.27	.40
Arginine	.46	.79
Tryptophan	.09	.15

Osborne and Mendel showed in 1914 that zein, the major protein of corn, was nearly devoid of lysine and tryptophan. A diet containing zein as the only protein was incapable of supporting growth in young rats. Adding pure lysine and tryptophan together (but not singly) to the zein gave good growth and demonstrated clearly for the first time that these amino acids are essential dietary components (5). The need for improving dietary protein in cereals occurs largely in developing nations. If maximum food utilization is to be achieved in these areas, we must blend locally available cereals and protein concentrates, including legumes in order to provide the required balance of amino acids, minerals, vitamins and calories. Fortification of these cereal blends with synthetic amino acids results in improvement of protein quality (6).

Another approach to the problem of improving the nutritional quality of dent corn protein is to add amino acids to the grain (7).

So much has been said and written of the reasons for and remedies of malnutrition, but so little progress seems to have been made in actually alleviating it. This is due to the low incomes of the people in the developing nations.

A series of studies begun at Purdue University in 1946 sought to approach the problem of protein deficiency by correcting the poor quality of the protein in corn. In 1963, Drs. Edwin Mertz and Oliver Nelson, and their graduate student, Lynn Bates, perfected two new hybrid varieties of corn which included the genetic stocks opaque-2 and floury-2. These two new genotypes had nearly twice as much lysine and tryptophan and better total protein balance and quality than regular corn. Both of these varieties are referred to today as "high lysine" corn (8).

THE SIGNIFICANCE and IMPORTANCE of HIGH LYSINE CORN

Dr. D. E. Alexander of the University of Illinois recently described the importance of high lysine corn as follows: "The significance of the opaque-2 discovery is possibly not recognized by many. To illustrate: Let us assume that the 1968 U. S. corn crop (about 4.4 billion bushels) had been of the opaque-2 type with adequate lysine and tryptophan content. The crop fed directly to humans would have met the caloric-protein requirements (3200 calories, 80 grams of protein per day per person) of the United States, Mexico, Peru, Colombia, Bolivia, Ecuador, Chile, and enough would have been left over to feed 46 million Indians (9).

Mertz et al. (8) reported the exciting results of rat feeding tests obtained with opaque-2 popcorn maize harvested in the fall of 1964. Opaque-2 kernels in high-protein background when fed at a 15% protein level give a rate of growth which is equal to that of the milk protein casein supplemented with cystine. Data showed that the opaque-2 maize produced excellent growth response and suggested that this type of corn has a PER (protein efficiency ratio) value which is 62% to 110% greater than ordinary corn. Lysine appeared to improve the PER value of the opaque-2 maize.

R. A. Pickett, Department of Animal Sciences, Purdue University, Lafayette, Indiana, found that the protein quality of opaque-2 corn is similar to that of an isonitrogenous diet of normal hybrid corn plus soybean meal when fed to swine at the level of 11.6% total crude protein. He also reported that opaque-2 corn supplemented with vitamins and minerals gives a diet which is adequate to support normal growth and feed conversion in finishing pigs, and that the higher tryptophan levels of opaque-2 corn may be the major contributing factor to its value (4).

Further light is shed on the importance of High Lysine Corn by Bressani of the Institute of Nutrition of Central America and Panama (INCAP), Guatemala City, Guatemala, C. A., who reported that the nutritive value of the protein of the opaque-2 corn is high and its quality is about 90% of that of skim milk as tested in children. The results also indicate that in the presence of protein concentrates such as cottonseed or soybean flour, the better nutritive value of the opaque-2 corn protein as compared to common corn cannot be demonstrated. However, higher weight gain of rats was obtained when the protein concentrates were mixed with the opaque-2 corn (10).

The inclusion of the opaque-2 gene in common corn appears to be a practical approach to the problem of improving the protein quality of human diets based on corn, thus improving the nutritional status of protein-deficient populations.

The biggest problem confronting the dry miller today is the wide variation in the physical and chemical properties of the different hybrids of corn that reach the mill for processing. Therefore, it is most desirable for the miller to know the properties of the raw material he is going to deal with. The advancements and improvements of his business has been made on a trial and error basis, a process which all of us know is slower and more costly than one founded on scientific knowledge.

Structure of the Kernel of Dent Corn

The kernel of corn is a one-seeded fruit. This type of fruit is known as a "caryopsis". It will be seen from the cross-section of the kernel of corn (fig. 1) that it consists essentially of the following parts:

Bran or seed coat
Floury endosperm
Horny or hard endosperm
Germ or embryo
Tip cap

The pericarp, the outermost part of the kernel and a major part of what the miller knows as bran, is composed of several layers:

Epidermis
Mesocarp
Cross cells
Tube cells
Seed coat

THE KERNEL OF DENT CORN

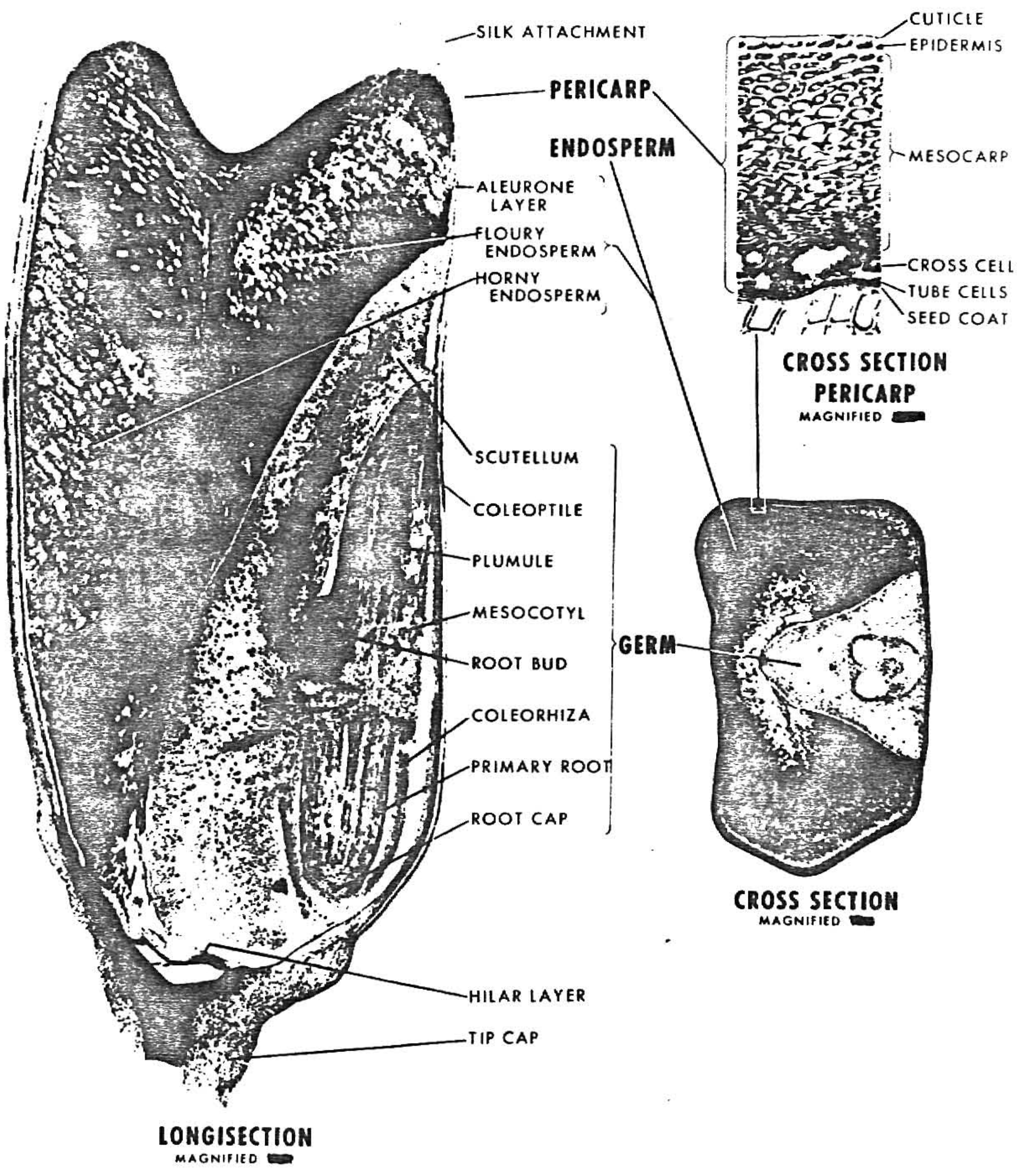


FIGURE --1

The outermost layer of cells of the endosperm is called the aleurone. This layer of cells contains protein and oil but no starch. The remainder of the endosperm contains starchy endosperm with large amounts of starch together with more or less protein and little oil and horny endosperm, the high protein portion of the endosperm. It is called horny endosperm, because the relatively high amount of protein in the cells gives a horny appearance to the cut surface. (fig. 4) Horny endosperm is much harder than starchy endosperm.

The germ or embryo of the cereal grain kernel is composed of the embryonic axis and the scutellum. The embryonic axis is an embryonic plant which develops at germination to produce the seedling. The scutellum serves as a feeding organ for this development and contains some materials which are used for nutrient of the germinating seed. The germ is a structure separate from the endosperm, as well as from the nucellar layer or seed coat. The germ contains little starch, but much oil and protein.

At the base of the corn kernel, inward from the tip cap, is the hilar layer, a dark disk-shaped structure that becomes visible when the tip cap is removed.

TABLE III

Components of Corn Kernel
of Typical U. S. Dent Variety (11)

	% by Weight (M.F.B.)	% Oil-M.F.B. (Ether Extract)	% Protein (Nitrogen x 6.25)	Ash	Starch
Whole corn	100.0	4.8	9.2	1.4	72.0
Endosperm	82.0	.9	9.0	.3	86.0
Bran	5.0	1.0	3.5	.5	7.5
Germ	12.0	34.5	18.0	10.0	9.0
Tip Cap	1.0	3.8	9.3	1.5	5.3

COMPARISON OF THE KERNEL OF DENT CORN AND OPAQUE-2 CORN

A high proportion of the endosperm of ordinary corn is horny or vitrious. There is a marked difference in the degree of packing of the starch granules. In dent corn the starch granules are so tightly packed that they have flattened areas or facets. In contrast, the endosperm of the opaque-2 corn has an open, almost sponge like character. The lower density of packing is reflected in a smoother surface and generally round appearance of the starch granules. (12)

The opaque-2 gene produces corn kernels that are completely opaque to transmitted light, in contrast with the brilliant translucency of normal dent corn kernels (figs. 2, 3, and 4). The bulk density which measures the composite of kernel density and packing volume, is 13% less for opaque-2 than for normal corn (13).

Optical microscopy shows that the protein network in endosperm cells of normal corn is composed of an amorphous matrix in which granules averaging about 2 microns in diameter are embedded. That these granules are rich in zein is demonstrated by their solubility in 80 percent ethanol. High-lysine corn, with submicroscopic granules clearly resolved only in the electron microscope, has a much lower content of zein than normal corn. The small size of subcellular protein granules in high-lysine corn correlates with the reported difference in zein content of the two types of corn (14).

REVIEW OF LITERATURE

The available literature shows little work reported concerning the dry milling of high lysine corn. O. L. Brekke of the Northern Utilization Research and Development Division of the United States Department of Agriculture (15), reported on the effects of different tempering treatments on

FIGURE -- 2 Kernal of dent corn (left) and HL-67 high lysine corn (right)

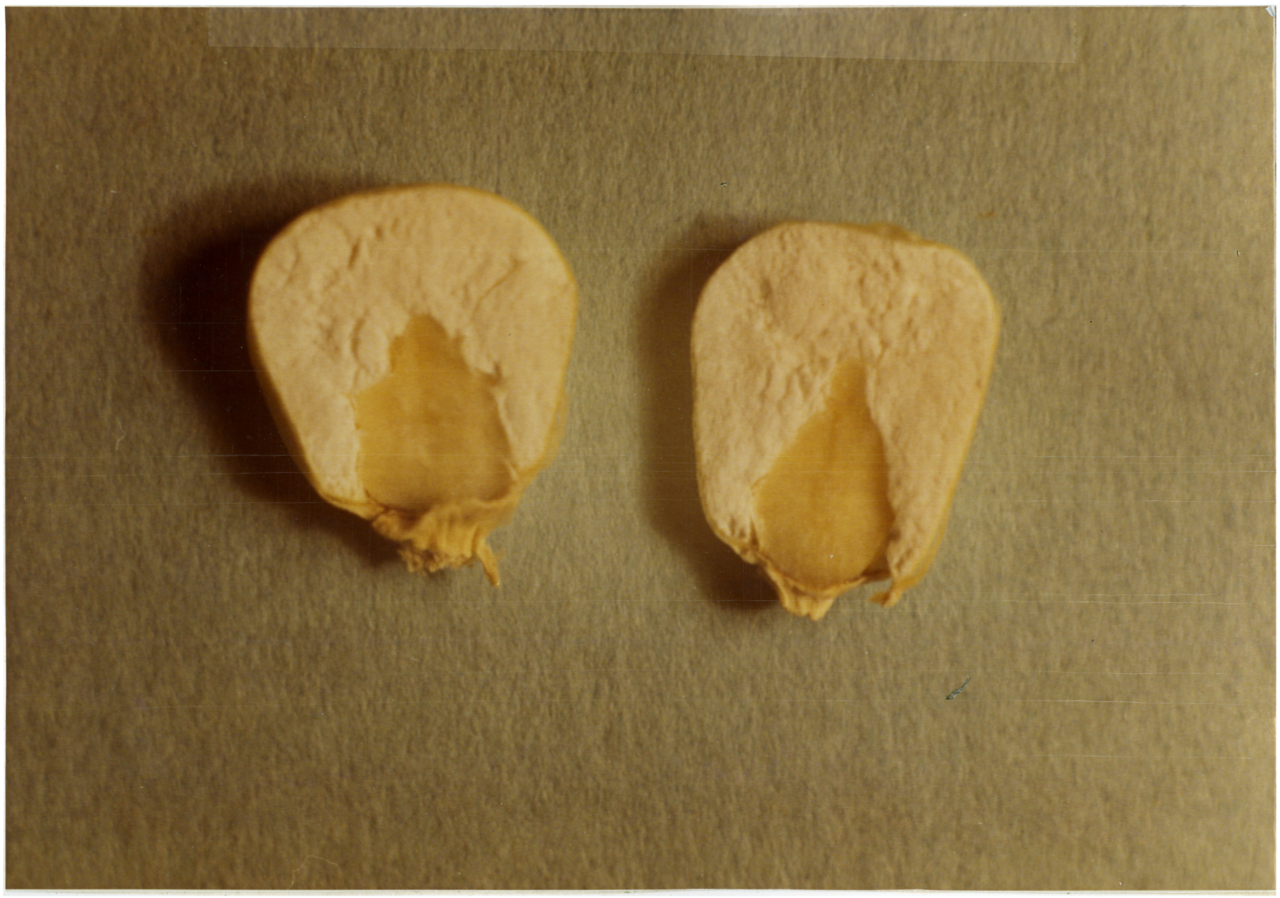


FIGURE 3 -- Section of the kernel of high-lysine corn

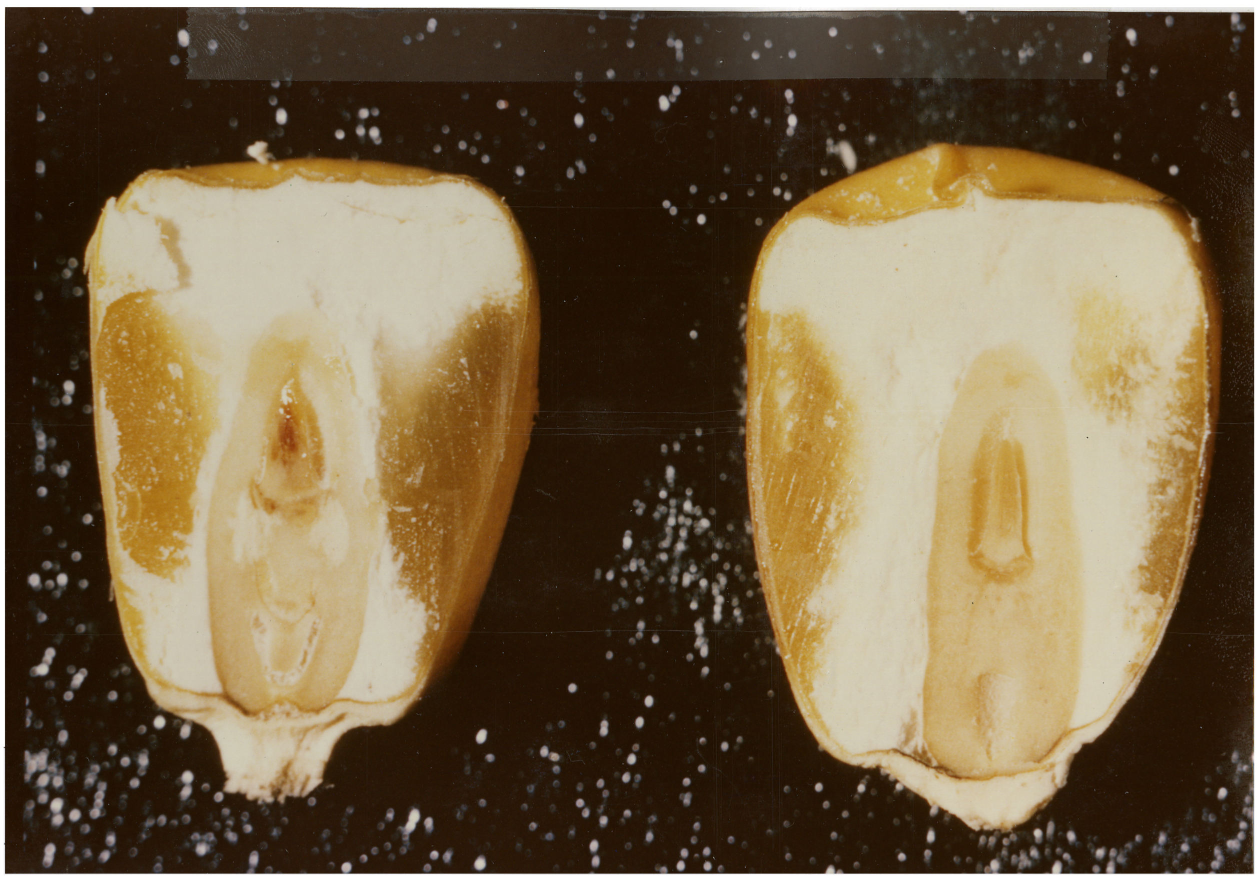


FIGURE 4 -- Section of the kernal of dent corn

the milling properties of opaque-2 corn. With an 18 percent first temper followed by steaming and a hot water dip, the yield of low-fat prime products compares favorably with that from yellow dent corn and the fat content is comparable to that of the hand-dissected endosperm. However, the opaque-2 corn produced a much lower yield of grits, more meal, and more flour.

W. R. Wichser (16) describes the milling differences between opaque-2 corn and normal dent corn. He points out that after the degermination system of milling opaque-2 corn the bran would remain stuck to the endosperm and germ. Even though the endosperm was fractured, the bran held the pieces together. He also found that conditioning the opaque-2 corn to 14 percent moisture ahead of the high moisture tempering for degermination improved the separation of products, the pieces of endosperm held together by the bran did break off and the germ, being tougher, withstood the process without breaking up. Concentrating the germ was done by repeated rollermill grinding and sifting of the material. Gravity table separation was attempted, but no good separation was effected. The use of gravity tables is useful in concentrating germ when milling yellow corn.

DRY-MILLING DENT CORN (Fig. 15)

The process of milling cereals to produce meal or flour from which food products are made is an old industry. Corn is dry milled by one of two methods. The old process, the stone milling system, produces a corn meal that is essentially the ground whole corn. The presence of the germ in corn meal shortens the shelf life of the product, but its inclusion enhances the nutritive value and flavor of the fresh product. The oil in the germ becomes rancid in time, making the meal unsuitable for food. Grinding or crushing the grain between two flat stones marked the beginning of the art and science of milling. Through the years corn milling developed by stages until today it has become a refined, complex and scientific process. Nevertheless, there are many mills in the world where corn milling is still done on mill stones.

In the new process, corn is passed through a series of cracking and reduction rolls. Sieves separate the floury endosperm, germ and hulls. This is the process we are going to talk about.

The objectives of dry corn milling have been stated as follows (11):

1. To produce the maximum percentage of clean grits, containing minimum fat and specks. (Specks include primarily black root caps or any other impurities that detract from appearance.)

2. To recover the maximum percentage of the endosperm as clean meal, while producing minimum flour. This last statement should apply only to hard corns. The difficulty in producing large grits from floury corn kernels can logically be explained by the fragility of the endosperm resulting from its loose, open structure.

3. To recover the maximum percentage of clean germ of high oil content and maximum particle size.

Stated in another way, the objectives are to make the cleanest separation of endosperm, bran and tip caps, and germ, while recovering the maximum of endosperm as clean grits.

The object of dry milling is the separation by mechanical means of as much as practical of the endosperm from the corn in the form of grits and flour in the purest state possible, free from the substances and impurities foreign to corn and of the germ and bran covering of the corn itself.

The fundamental principles in modern day dry milling involves four distinct operations which constitute the process or system.

1. Cleaning and otherwise preparing the grain for grinding (tempering or conditioning).

2. Dehulling and degerminating.

3. The grinding and sifting of the grain.

4. Purification of products.

The sifting operation depends on the sieve opening, and thus is a mere sizing operation which may be quite independent of weight.

The last operation may be included in the third, as being part of the separating system. It differs in principle, in that air is used and helps to classify the product into lighter and heavier particles, therefore, it is a separation by weight.

In the gradual reduction of the grain and the classification of stocks by several distinct separations into grades or sizes, each stream is treated by itself thus accomplishing a much better separation of products.

Cleaning

Cleaning of corn is a difficult and important operation for corn millers. It should remove all foreign material and other grains from the corn. The equipment used in the industry includes mainly the milling separator, scourers, gravity tables, washers and whizzers and electrostatic separators for the removal of rodent pellets.

Tempering or Conditioning of Corn

The tempering or conditioning of corn is the next step. The effective separation of products during milling depends largely on proper conditioning of the grain by addition of cold or hot water or steam, either separate or in combination, followed by a rest period of from 1 to 24 hours.

The objectives of conditioning have been stated by T. E. Stivers et al. (1955) as follows (11): (1) to cause loosening of the germ, (2) to moisten the germ more than the endosperm, (3) to cause loosening of the bran and at the same time toughen it, making it easier to remove in large pieces, (4) to toughen the tip cap so it will stay with the bran, and thus prevent the small black root cap from becoming dislodged in the degerminators and causing black specks in the meal or grits, and (5) to moisten the endosperm for milling, which helps produce maximum grits and minimum flour.

To achieve the objectives of conditioning, the conditioning process must be matched to the degerminator step, which is one of the more important operations in corn milling.

Degermination

In modern day corn milling, several degerminators are presently used either separate or in combination. The "degerming and dehulling" as usually called may be accomplished by use of Beall degerminators; Entoleters; granulators and or roller mills. According to one estimate whenever a maximum of large sized flaking grits are required (17), 85-90% of the mills degerminating corn use Beall degerminators.

For normal corn milling, the moisture content involved during degermination is still relatively high, between 18 to 24%. After degermination the stock is dried if necessary, cooled, and then milled immediately by a roller mill and grading system to separate germ and bran and to recover endosperm in the form of grits, meal, and flour. Many millers agree that this drying and cooling process is not beneficial for grits which require a low fat content and have expressed a need for degerminators with the following features (18): High yields of grits in the degerminator product streams (particularly flaking grits) minimum "fines" production, good degermination and dehulling, (good release of germ and hull from endosperm), minimum grinding of the released germ and hull, minimum operator attention, minimum maintenance, high capacity, and low power requirements.

The Beall consists of a cast-iron, cone-shaped rotor, revolving on a horizontal shaft in a conical cage. Part of the cage is fitted with perforated screens and the remainder with plates having conical protrusions on their inner surface. The cone has similar protrusions over most of its surface. The small or feed end of the cone has spiral corrugations to move the corn forward; the large end is corrugated in an opposing direction to retard the flow. The product leaves in two streams. One stream, discharged through the perforated screens, contains a major portion of the released germ and hulls, fines and some of the large grits. The second stream, which normally contains a major portion of the large grits, escapes through an opening in an end plate facing the large end of the cone. A hinged gate with an adjustable weight restricts flow of this latter stream.

The granulator has a cylinder composed of eight knives or blades rotating on a horizontal shaft. A perforated screen surrounds about three-fourths of the cylinder's surface, and all the corn must pass through this screen. Some millers operate with knife edges on the rotor leading and some prefer to have them trailing. In the latter case, more of an extrusion effect is obtained. The granulator may also be fitted with two stationary knives.

Main advantages of the granulator claimed are as follows:

1. It has about twice the capacity of the Beall.
2. It needs half the power.
3. It gets about 1% more of the grits.
4. It produces more germ with equal fat.
5. It makes about 2% less flour.

The Entoleter degerminator is similar to the machine used for insect control, except that the rotor turns about a row of stationary pins. The

Entoleter will release a great percentage of whole germs. The hulls will remain practically intact. However, some of the germs remain attached to the tip cap. Comparatively, the Entoleter degerminator produces less flour, less large grits but more intermediate grits than the other degerminators.

Roller mills probably are the oldest means of degerminating. With proper corrugations, roll settings and conditioning, a very good release of germ can be accomplished. However, on a mill set for maximum grit extraction, the germ is broken into smaller pieces on a roller mill. Only a very long system of rolls, sifting and purification will produce low fat products. In general, the oil production will be less than the other means of degermination. This is partly offset by a high extraction of grits and less flour.

The Corn Drying, Cooling, Grading and Aspirating Cycle

The miller controls moisture content of degerminator stock for roller operation by adjusting the amount of moisture removed during drying and cooling or if no dryer is used ahead of the roller operation, by selecting corn of proper moisture content and adjusting temper moisture.

The degerminated stock is dried on the conventional rotary steam tube dryers and cooling is done in either rotary type cereal coolers or in fluid bed-type coolers. The drying and cooling are necessary for additional processing. After drying and cooling the thru stock is sifted or classified by particle size and enters into a conventional long reduction system. The objective of this system is to remove the bran and germ and release a maximum amount of clean large grits. From the first sifting operation this material may be processed over gravity tables to insure a more complete separation of the large germ from the large grits before the grits are sent on to conventional aspirators, grinding rolls, and sifters. The germ which is removed throughout this part of the milling process is collected for processing in the oil extraction plant.

Classification or grading to size before aspirating, can be done on a plan sifter. Some mills make use of purifiers for the classification and purification of intermediate grits and meal.

Aspirators used in the mill can be the disc, louvre or wide thin stream types. The disc aspirator has the advantage of doing a more uniform job with fluctuating rates of feed such as sometimes are experienced. It is a good practice to have an aspirator over each roll to remove hulls, germs and black specks before grinding.

Corn Mill Roll Surface

The American type of corn mill has a total roll surface of approximately 5/16" per cwt. of finished product, using 9" diameter roll at 550 r.p.m. for the fast rolls. Break rolls have a differential of 2.5:1. Germ rolls have a differential of 1.5:1 or even 1.25:1.

Corn Mill Sifting and Purifying

Sifting data: The use of .65 to .70 sq. ft. of screen area per cwt. is ample for corn mills of 3000-4000 cwt. capacity. The sifting capacity would be divided about 40% for breaks, 30% for germ, 15% for reduction, and 15% for purifier and flour stock.

MATERIALS, EQUIPMENT, AND METHODS

A single lot of High Lysine corn coded HL-67 grown in northeast Kansas was used in this investigation. The corn was presumably dried by ambient air ventilation. The method of harvesting and moisture content at harvest is not known nor the soil treatment, if any, given at time of planting. The HL-67 corn showed slight damage by incipient infestation and has been fumigated twice since harvest. The corn contained crude fat 4.3; crude fiber 2.2; ash

1.3; and protein 9.90. Its test weight was 52.5 lb. per bu. at 12.3% moisture content.

Crude fat content of the corn and of the various fractions was determined by the AOCS Official Method for Fat Aa 4-38 Revised 1961. AACC procedures were used for crude fiber (32-15); ash (08-01); moisture (44-15), and protein (46-10). For the protein determination Alizarine Sodium Monosulfonate indicator was used instead of Methyl Red.

The experimental millings of HL-67 corn were carried out as illustrated by the different flow diagrams in figs. 7, 8, 9, with equipment shown by figs. 10, 11, 12, 13, and 14. They consist of the following components which are numbered according to the process flow.

1. The Carter Dockage Tester (fig. 10) was used for the removal of broken corn and foreign material at the following settings (19).

a. Set the air control at Number 1

b. Set the feed control at Number 10

c. Use no riddle, and

d. Use the Number 3 sieve in top sieve carriage and no sieve in the second or bottom sieve carriage.

2. The "pill-coater" type mixer (fig. 11) facilitated rapid, uniform mixing of water with the HL-67 high lysine corn samples for the experimental milling. The correct amount of cold water was added to the corn in the revolving tub from a 250-ml. buret. The water was dispersed in a spray with air. The tub was turned for about 5 minutes, at which time the corn no longer clinged to the surface. The tub is driven by a work arbor fastened to the base. The arbor will slip over a slotted 1/2-in. drive shaft. A 3/16-in. bolt through the arbor completes the drive connection. This simple connection

made it possible to remove and replace the tub while the drive shaft continues to rotate.

The drive shaft which supports the tubs is mounted at an angle of 30 degrees and rotates at approximately 50 r.p.m. A single tub may be driven directly from the shaft of a 40:1 gear reducer driven by a 1750 r.p.m. electric motor.

3. Degerminator tests were made with an Entoleter Variable Speed Centrifugal machine type ESA fig. 12 fitted with a special rotor, stator and liner assembly (M-52719). The Entoleter degerminator is powered by a 3-hp electric motor. The rotor can be driven at any speed from 1,000 to 4,000 r.p.m. The rotor consists of two steel discs spaced approximately one inch apart each containing specially designed impactors.

4. The flow sheets for our Entoleter, roller milling and grading operation are the different HL-67 high lysine corn flows of the Milling Department at Kansas State University shown in figs. 7, 8, and 9.

The Roller Mill Experimental Unit shown in fig. 13 consists of a Richmond GYRO-LAB SIFTER. The sifter could hold six sieves 12" x 15½" gyrated at 330 r.p.m. on a circle 2¼-in. in diameter, six pairs of corrugated rolls and one pair of smooth rolls, fitted with a Texorope Vari Pitch Allis Chalmers gear reducer to change differential. The corrugated rolls have standard Saw Tooth (S.T.) or Getchell (G) corrugations operated dull to dull.

5. A Kice type F laboratory aspirator was used for the purification of stocks after proper grading. (fig. 14).

TABLE IV

ROLLER MILL SETTINGS AND PRODUCTS PRODUCED

FLOWSHEET: TWO-PASS MEDIUM SPEED ENTOLETER SYSTEM (Fig. 7)

Entoleter r.p.m. 1760 for the 1st pass and 2100 for the 2nd pass

MILL	Pre-break	1st-break	2nd-break	3rd-break	1st-chunk	1st-germ	2nd-germ
Corrugations per in.	24 G	5/6 ST	5/6 ST	7/8 ST	7/8 ST	12/12 G	12/14 G
Differential	1.3:1	2.0:1	2.0:1	2.5:1	2.5:1	2.3:1	2.3:1
Clearance, in.	0.130	0.050	0.020	0.025	0.015	0.014	0.010

PRODUCTS (Chart I)	PARTICLE SIZE RANGE
Break grits	-14 + 22 mesh
Meal (low fat)	-22 + 62 mesh
Flour (low fat)	-62 + pan
Feed (bran+germ+tailings)	-4 + 14 mesh

Note: Same settings as above were used for corn with first temper only.

TABLE V

FLOWSHEET:	ONE-PASS HIGH SPEED ENTOLETER SYSTEM (Fig. 8)			
Entoleter r.p.m.	4,000 one pass only			
MILL	1st-break	2nd-break	3rd-break	1st-germ
Corrugations per in.	7/8 ST	7/8 ST	12/14 G	12/14 G
Differential	1.3:1	1.8:1	2.5:1	1.5:1
Clearance, in.	0.025	0.015	0.015	0.010

PRODUCTS (Chart II)	PARTICLE SIZE RANGE
Break grits	-14 +22 mesh
Meal (low fat)	-22 +62 mesh
Flour (low fat)	-62 +pan
Bran	from aspirators of all break stock
Germ	+6 mesh 1st break and +10 mesh 3rd break
Tailings	+8, +10, +14 mesh 1st germ roll

TABLE VI

FLOWSHEET:	ALL ROLLER MILL SYSTEM (Fig. 9)					
MILL	1st-break	2nd-break F	2nd-break C	germ	1st-Siz.	2nd-Siz.
Corrugations per in.	5/6 ST	7/8 ST	7/8 ST	7/8 ST	12/14 G	12/14 G
Differential	1.3:1	2.0:1	2.0:1	2.0:1	2.0:1	2.0:1
Clearance, in.	0.060	0.028	0.028	0.016	0.010	0.006

PRODUCTS (Chart III)	PARTICLE SIZE RANGE
Break grits	-10 +14 mesh
Break grits	-14 +22 mesh
Meal (low fat)	-22 +62 mesh
Flour	-62 + pan
Feed (bran+germ+tailings)	+4, +6, +8, +10 and +22 2nd Siz.

Experimental Operation. Grinding tests were run in triplicate for each milling system. HL-67 high lysine corn, after cleaning in the Carter Dockage Tester for the removal of broken corn and foreign material as specified in the reference (21), was sprayed with sufficient tap water to raise its moisture content for the first temper, from 12.3 to 16%; it was then given a rest period of 16 hours. For the second temper, approximately 5% more water was added about 15 minutes before the corn was degerminated.

In addition, a test was made with corn with only first temper, using the Two-Pass Medium Speed Entoleter System.

All tempering was done at room temperature, using the "pill-coater" unit (fig. 11).

Tempered corn was then placed in a hopper and fed by a scale feeder at 20 pounds per minute to the Variable Speed Entoleter-Aspirator-Degerminator set at the speed as shown in the flow sheets (figs. 7 and 8).

The degerminated product was collected in an empty bag just below the Entoleter housing. Upon completion of each degerminator test run, the ground material in the test bag was weighed and the weight recorded to determine the amount of loss in the system. This material was then sifted in the Richmond GYRO-LAB SIFTER employing screens for size separation, followed by aspiration for hull removal in the Kice laboratory aspirator (fig. 14). Stock needing reduction and removal of bran was further fractionated by the experimental roller mill at the settings shown in the above flow sheets.

Three tests were made by the All Roller Mill System. The roll settings, and other data are shown in tables VI and X.

In another series of Entoleter degerminator tests, the effect of rotor speed on product release, product yields, and product characteristics was studied at the following levels: 2000, 2400, 2838, 3150, 3600 and 4000 r.p.m. The degerminated product from the above rotor speeds was fractionated for size separation as before.

RESULTS AND DISCUSSION

Data on the dry milling of high lysine corn for each of the experimental flow systems used are given in tables IV, V, VI, VII, VIII, IX and X, including the number of runs for each system.

The difference in dry milling of high lysine corn and ordinary dent corn is related to the variation in internal structure of the endosperm. The difficulty in producing large grits from high lysine corn can logically be explained by the fragility of the endosperm, resulting from its loose, open structure (fig. 3).

High lysine corn can be conditioned to mill fairly satisfactorily, but with low yields of table grits and no flaking grits.

The initial dry cleaning of high lysine corn presented no problems nor did the conditioning step. However, some investigators had pointed out that in washing the corn it may be necessary to adjust the action of the washer since the density of the kernel is closer to the density of water than normal corn. The lower density of high lysine corn is because of the preponderance of floury endosperm.

The degerminator tests conducted immediately showed that high lysine corn mills very much different from normal dent corn. Most of the bran or hulls remained stuck to the endosperm and germ, and even though the endosperm was fractured, the bran held the pieces together (fig. 5 and chart III of products). To solve this problem, the Entoleter degerminator was used at higher speeds to achieve a good bran release.

One of the most significant effects of varying the degerminator speed was the pronounced influence on the amount of germ, bran and flour released from corn. At low speed (1760 r.p.m.) the bran would remain stuck to the endosperm; at high speed (4000 r.p.m.) the Entoleter degerminator released a greater percentage of whole germs, the hulls were freed in large pieces and could easily be removed by aspiration (fig. 6 and chart II or products). Comparatively, the Entoleter degerminator at this speed produced more flour, less grits and more meal.

Comparison of the Dry Milling Systems Used. In general, all four dry milling procedures used produced flour of good quality with low oil content (0.5 to 1.2%). Production of the flour fraction decreased and that of +22 grits increased by using the Two-Pass Medium Speed Entoleter System (fig. 7).

The One-Pass High Speed Entoleter System (fig. 8) produced, as expected, the highest percentage of flour of excellent quality with the lowest oil content (0.5 to 0.8%) and the cleanest bran (chart II of products). Sufficient degermination was obtained with this system for practically all grits in the -14 +22 mesh range so that the need for further degermination on roller mills is eliminated. Thus, the subsequent milling flow is shortened; the problem is then limited to separation of germ and hull fractions from grits by aspiration or scalping off in the top screens of the germ section.

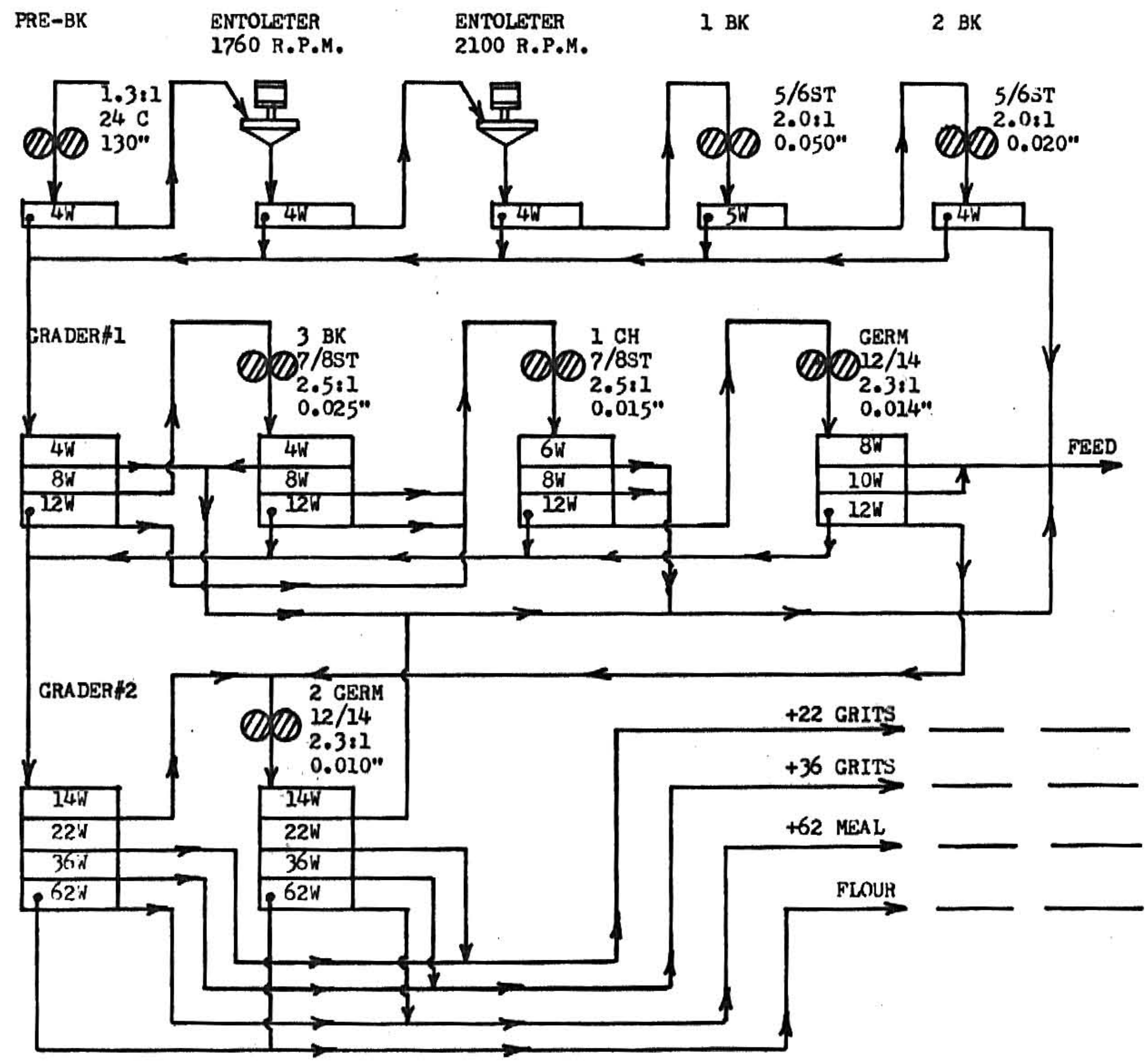
The All Roller Mill System produced the lowest percentage of endosperm, yet it was the only system that produced a clean fraction of -10 +14 grits as shown in the chart III of products. Roller mills in general will produce larger grits, but a longer system is needed to recover the broken germ.

For maximum recovery of oil, the One-Pass High Speed Entoleter degerminator was best. Use of a second temper proved to be beneficial as shown by the differences as tabulated in table VII (corn with 1st and 2nd temper) and the data in table VIII (corn with 1st temper only). Second temper lowered the attached hull count and possibly has some influence on attached germ count.

Sieving tests of the Entoleter degerminator stock at different rotor speeds show that there is a positive correlation between speed and percent flour released. High separation of bran and germ came with the highest rotor speed (4000 vs 2000 r.p.m.) but at reduced yields of larger grits. The yield of grits of various particle sizes, germ and hull (corn processed) was calculated in percent of total products retained. The results are shown in the Results and Discussion section and tabulated in Table XI.

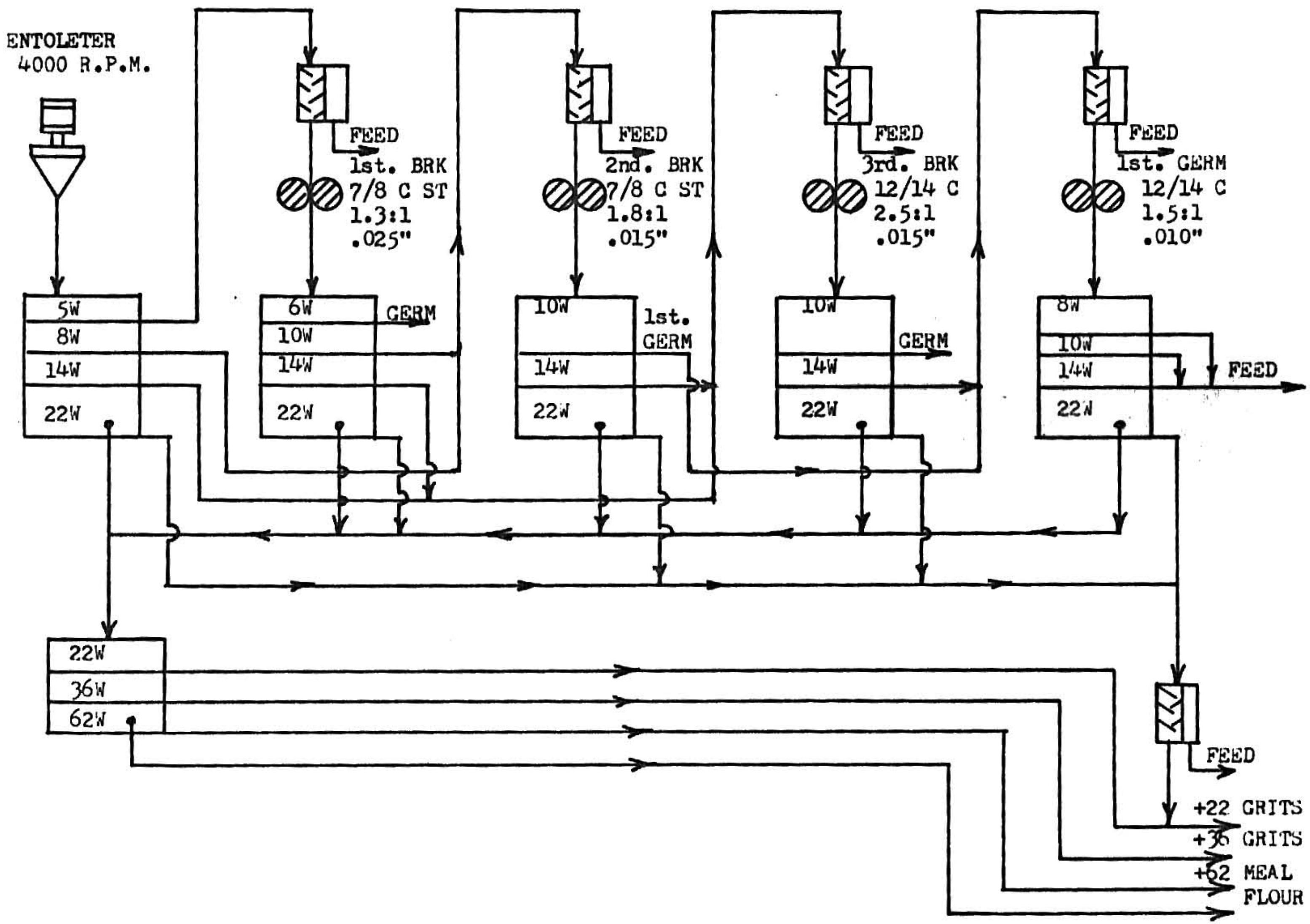
FIGURE -- 6 Clean bran

FIGURE -- 5 adherence of bran to endosperm



HIGH LYSINE CORN FLOW
REV. NOV. 15, 1969

FIGURE --7 TWO-PASS MEDIUM SPEED ENTOLETER SYSTEM



HIGH LYSINE CORN FLOW
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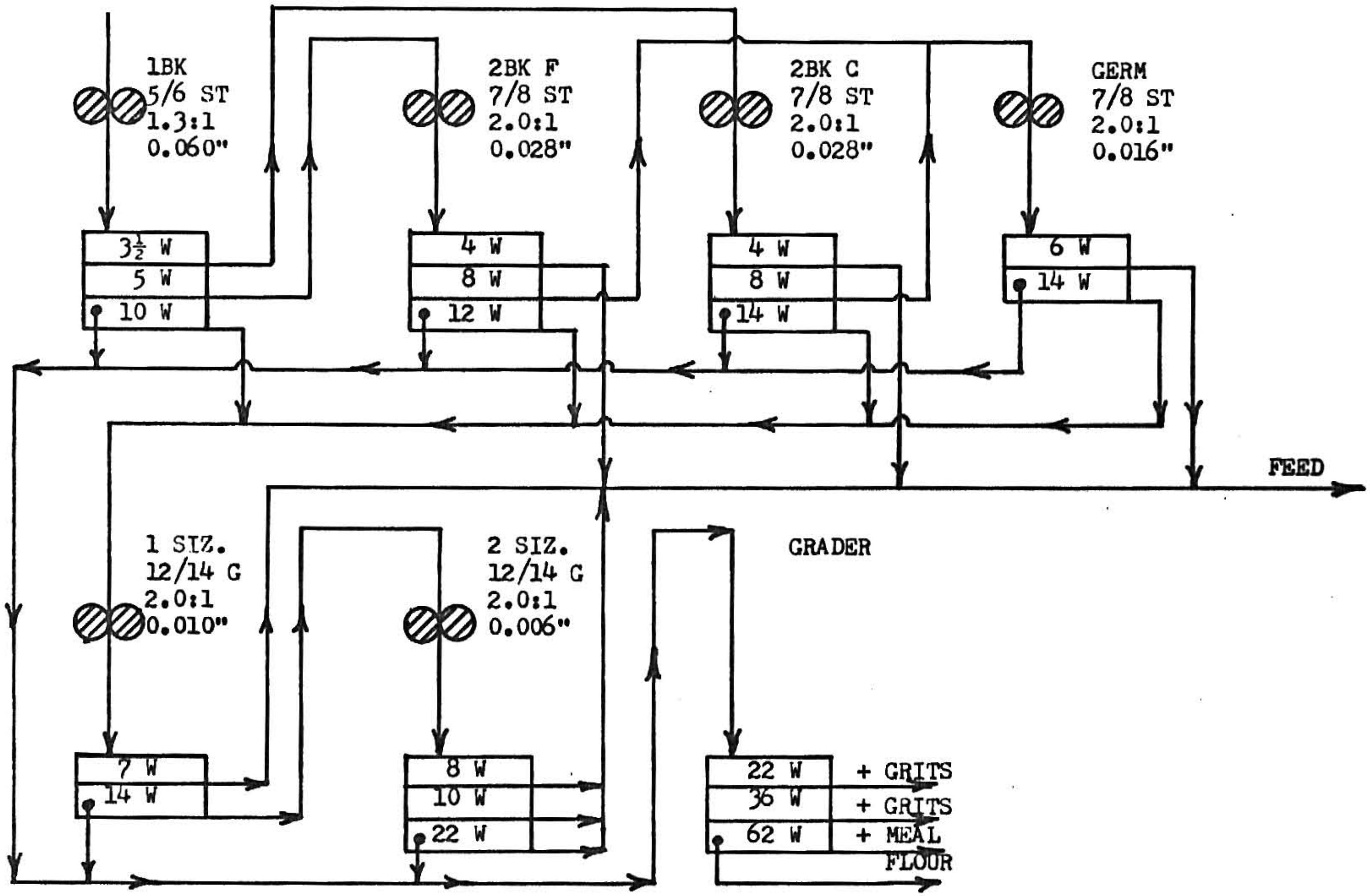
FIGURE --8 ONE-PASS HIGH SPEED ENTOLETER SYSTEM



HIGH LYSINE CORN FLOW
REVISED 06-23-70

FIGURE --9 ALL ROLLER MILL SYSTEM

FIGURE 10-- CARTER DOCKAGE TESTER

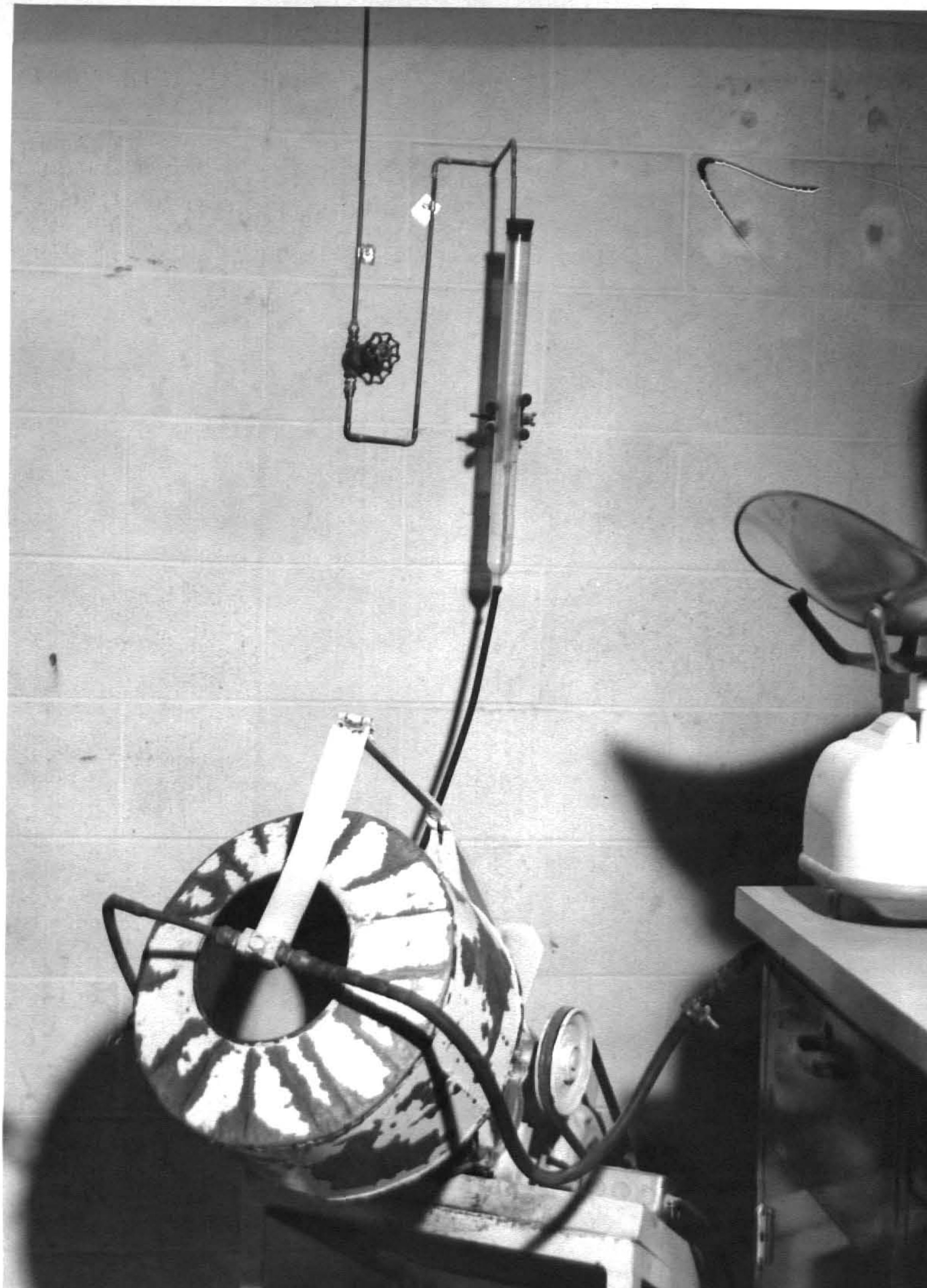


FIGURE 11-- "PILL-COATER" TEMPERING UNIT

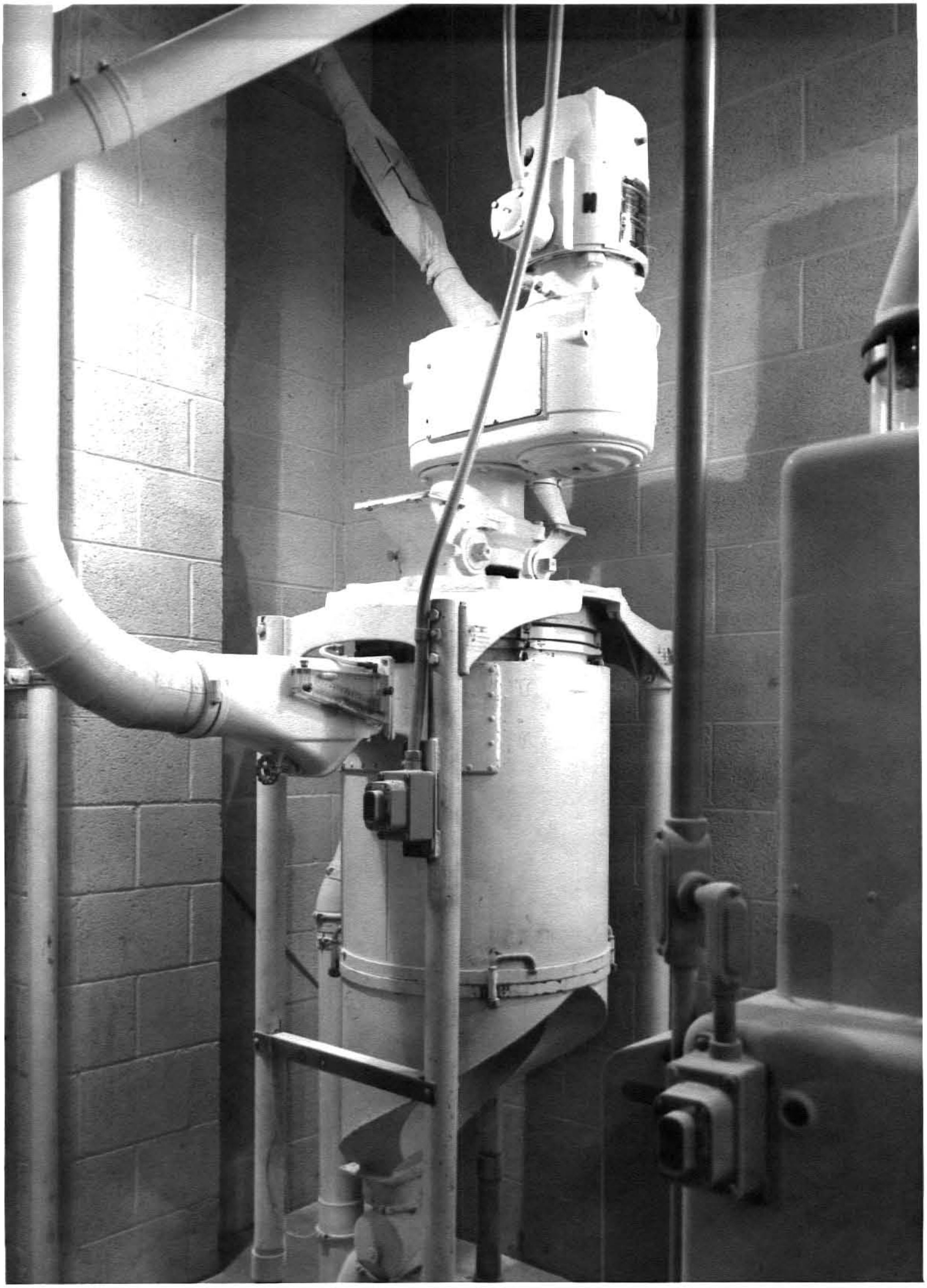


FIGURE 12-- ENTOLETER DEGERMINATOR UNIT

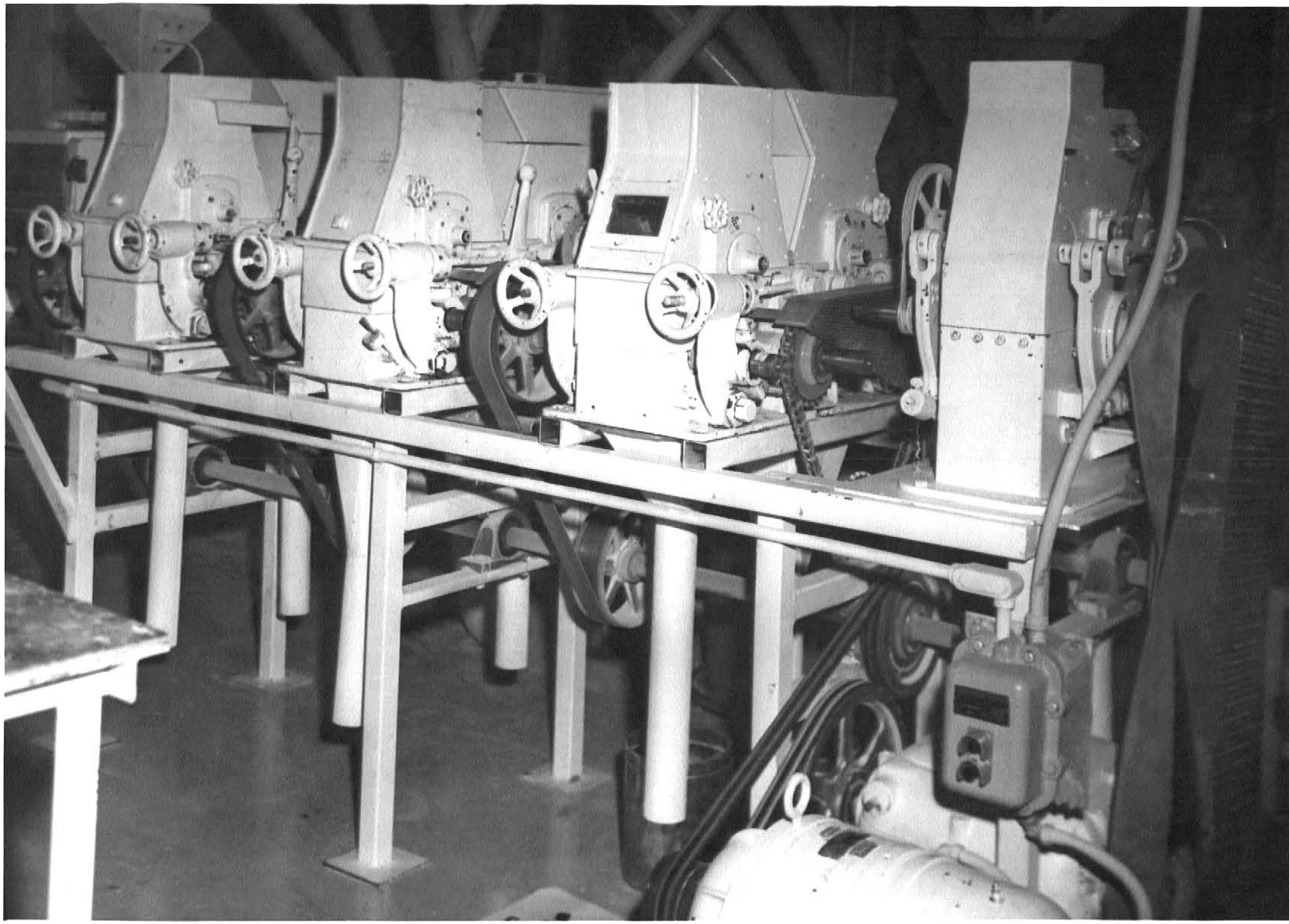


FIGURE 13-- ROLLER MILL EXPERIMENTAL UNIT WITH TEXROPE VARI PITCH GEAR REDUCER AND RICHMOND GYRO-LAB SIFTER

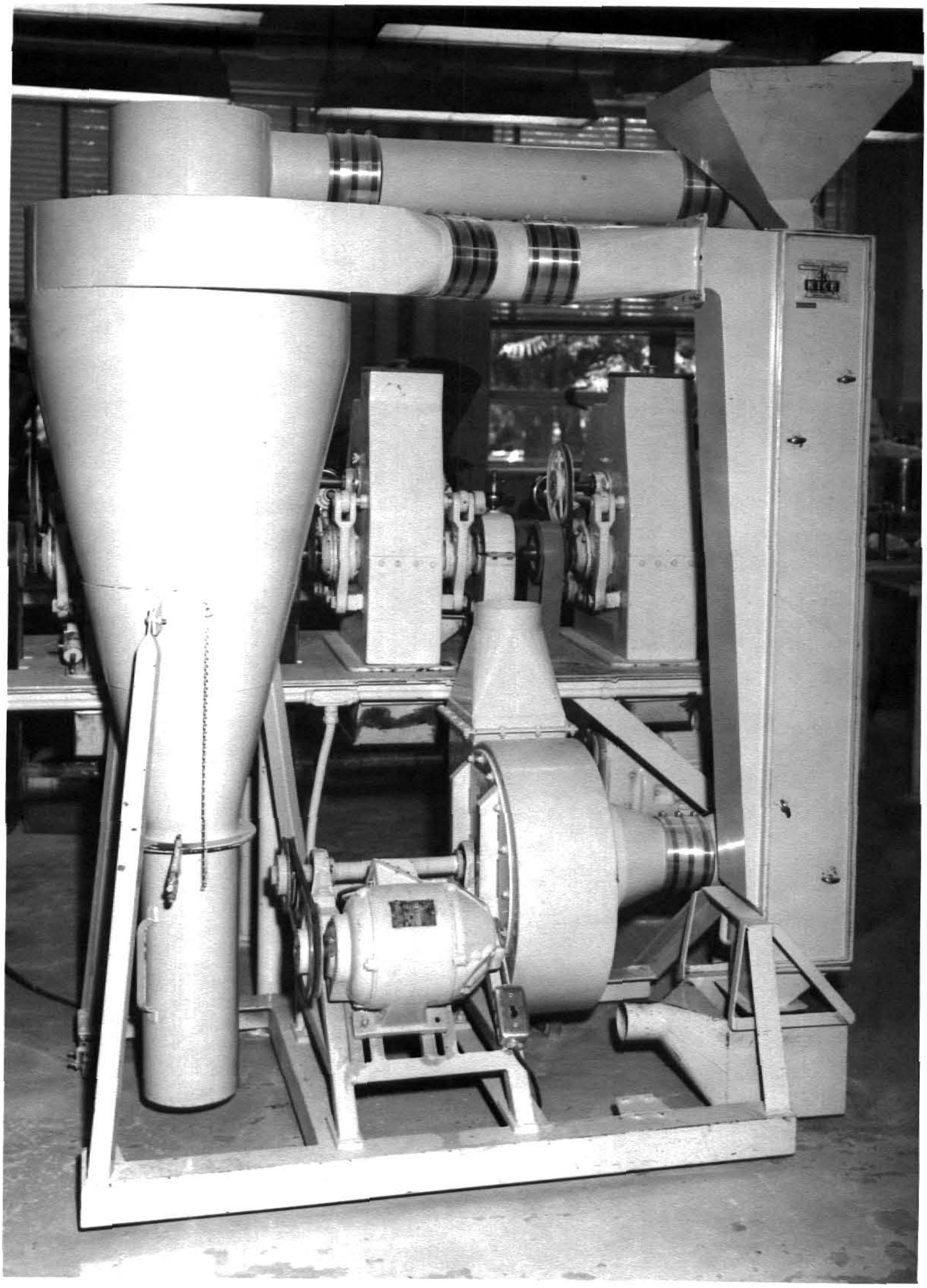


FIGURE 14-- KICE TYPE F ASPIRATOR

TABLE VII

TWO-PASS MEDIUM SPEED ENTOLETER SYSTEM
(Corn with 1st and 2nd temper)

RUN-1 (J-13, J-17)

Product	Moisture	Protein	Ash	C. Fat	% of Total Product
	%	%	%	%	
Grits +22	14.9	8.0	0.54	1.0	31.4
Grits +36	14.4	7.1	0.43	0.6	15.8
Meal +62	13.3	6.4	0.37	0.8	9.4
Flour	13.2	6.0	0.32	0.9	7.8
Feed	14.7	15.4	3.9	11.5	35.6
		RUN-2 (J-19, J-23)			
Grits +22	14.4	8.0	0.58	1.3	32.8
Grits +36	14.3	7.3	0.45	0.9	15.9
Meal +62	14.0	6.7	0.39	0.5	9.5
Flour	13.6	5.9	0.33	0.7	8.6
Feed	12.5	15.7	3.9	11.0	33.1
		RUN-3 (J-25, J-29)			
Grits +22	14.4	8.4	0.6	1.3	35.0
Grits +36	14.3	7.2	0.38	0.9	15.6
Meal +62	14.3	6.5	0.38	0.8	8.9
Flour	13.9	5.9	0.26	0.8	8.6
Feed	13.9	14.9	3.6	10.1	31.8

TABLE VIII

TWO-PASS MEDIUM SPEED ENTOLETER SYSTEM
(Corn with one temper only)

RUN -1 (I-322, I-326)

Product	Moisture	Protein	Ash	C. Fat	% of Total Product
	%	%	%	%	
Grits +22	13.7	9.5	0.82	1.9	30.5
Grits +36	16.8	7.5	0.39	0.8	17.6
Meal +62	16.4	6.7	0.29	0.51	12.4
Flour	16.1	6.2	0.26	0.9	9.8
Feed	12.7	15.8	4.1	12.5	29.7
RUN-2 (I-329, I-338)					
Grits +22	15.3	7.8	0.55	1.8	30.2
Grits +36	15.8	7.2	0.39	0.8	18.8
Meal +62	16.6	6.8	0.33	0.6	11.3
Flour	16.1	6.4	0.24	1.0	10.7
Feed	11.0	16.3	4.0	12.7	29.0
RUN-3 (I-388, I-393)					
Grits +22*	15.9	8.6	0.79	2.3	32.4
Grits +36	15.9	7.8	0.5	1.0	18.3
Meal +62	16.3	6.9	0.41	0.7	10.0
Flour	16.2	6.5	0.4	1.0	10.9
Feed	11.2	15.8	3.8	11.4	28.4

*Combined +22 grit fractions

TABLE IX
ONE-PASS HIGH SPEED ENTOLETER SYSTEM
(Corn with 1st and 2nd temper)

Product	Moisture %	Protein %	Ash %	C. Fat %	% of Total Product
		RUN-1 (I-713, I-718)			
Grits +22	12.6	9.7	0.86	2.2	19.8
Grits +36	13.2	8.1	0.51	1.0	14.8
Meal +62	11.4	7.7	0.47	1.0	16.9
Flour	15.9	6.1	0.42	0.5	18.9
Feed	9.3	14.6	3.6	10.9	29.8
		RUN-2 (I-786, I-790)			
Grits +22	14.8	8.7	0.66	2.1	27.4
Grits +36	14.4	8.1	0.5	1.3	12.6
Meal +62	16.5	7.3	0.45	0.9	11.8
Flour	17.0	6.0	0.36	0.5	18.2
Feed	12.8	15.1	4.0	12.0	30.0
		RUN-3 (I-791, I-796)			
Grits +22	14.1	9.1	0.79	2.0	29.2
Grits +36	13.9	8.2	0.4	1.1	11.8
Meal +62	14.7	7.4	0.41	0.9	11.7
Flour	15.6	6.3	0.3	0.8	17.5
Feed	11.2	16.4	4.5	13.9	29.8
		RUN-4 (I-719, I-724)			
Grits +22	12.7	9.4	0.99	2.7	27.8
Grits +36	13.0	8.3	0.58	1.6	14.0
Meal +62	14.1	7.3	0.49	1.0	10.7
Flour	15.9	6.0	0.38	0.6	16.7
Feed	8.7	15.1	3.7	12.2	30.8

TABLE X

ALL ROLLER MILL SYSTEM
(Corn with first and second temper)

Product	Moisture	Protein	Ash	C. Fat	% of Total Product
	%	%	%	%	
		RUN-1 (I-918, I-922)			
Grits +22	15.6	8.2	0.70	1.5	28.2
Grits +36	16.3	7.1	0.47	0.7	16.0
Meal +62	16.9	6.4	0.34	1.1	10.1
Flour	16.8	5.7	0.30	0.8	9.7
Feed	12.8	14.5	3.5	10.1	36.0
		RUN-2 (I-923, I-927)			
Grits +22	16.0	8.1	0.72	1.8	34.5
Grits +36	16.1	7.0	0.49	1.3	13.7
Meal +62	16.6	6.2	0.34	1.0	8.9
Flour	16.6	5.8	0.27	1.2	7.9
Feed	12.6	14.1	3.20	10.2	35.0
		RUN-3 (I-928, I-932)			
Grits +22	15.9	8.4	0.84	2.2	29.4
Grits +36	16.1	7.3	0.56	1.3	15.1
Meal +62	17.1	6.4	0.36	1.0	12.0
Flour	16.9	5.7	0.31	1.0	11.4
Feed	13.1	14.0	3.4*	10.6	32.1

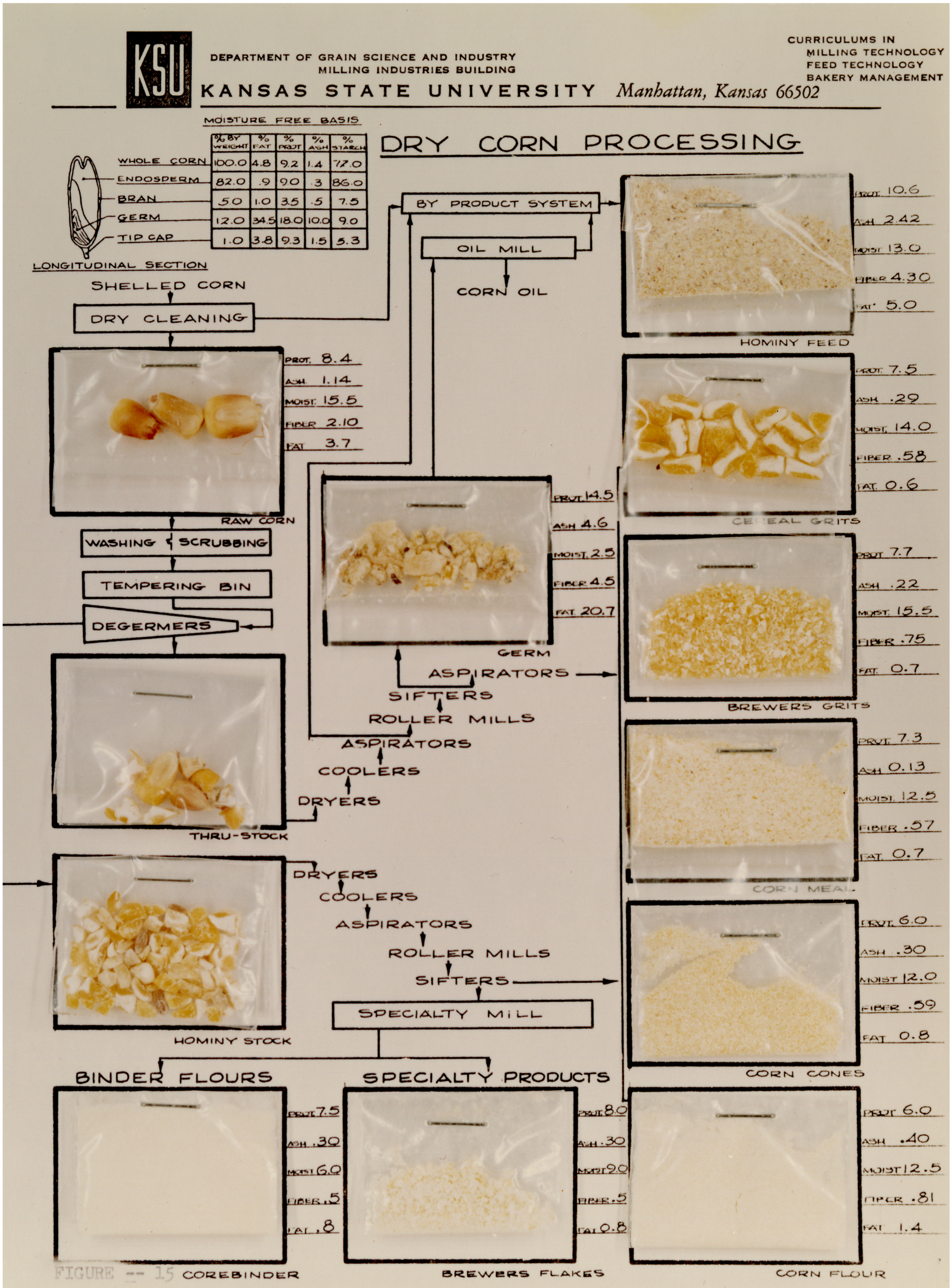
*Average of two replications

TABLE XI

EFFECTS OF ENTOLETER ROTOR SPEED ON PRODUCTS MADE

(R.P.M.)

Degerminated stock	2000 %	2400 %	2838 %	3150 %	3600 %	4000 %
+4W	59.3	39.2	21.9	12.4	13.3	5.3
+5W	14.8	20.0	19.6	17.6	17.2	12.7
+6W	5.3	8.4	10.0	11.3	10.0	8.9
+8W	4.8	7.0	9.4	11.8	10.6	10.0
+14W	7.0	10.5	15.1	17.3	17.2	19.5
+22W	3.7	5.8	8.9	10.3	10.6	14.0
+36W	1.9	3.1	4.8	6.0	7.7	10.5
+62W	1.5	2.5	3.7	5.2	5.4	6.9
Pan	1.7	3.5	6.5	7.9	8.1	12.7



DEPARTMENT OF GRAIN SCIENCE AND INDUSTRY
MILLING INDUSTRIES BUILDING
KANSAS STATE UNIVERSITY Manhattan, Kansas 66502
CURRICULUMS IN
MILLING TECHNOLOGY
FEED TECHNOLOGY
BAKERY MANAGEMENT
DRY CORN PROCESSING
MOISTURE FREE BASIS
% BY WEIGHT | % FAT | % PROT | % ASH | % STARCH
WHOLE CORN 100.0 4.8 9.2 1.4 77.0
ENDOSPERM 82.0 .9 9.0 .3 86.0
BRAN 5.0 1.0 3.5 .5 7.5
GERM 12.0 34.5 18.0 10.0 9.0
TIP CAP 1.0 3.8 9.3 1.5 5.3
LONGITUDINAL SECTION
SHELLED CORN
DRY CLEANING
BY PRODUCT SYSTEM
OIL MILL
CORN OIL
PROT. 10.6
ASH 2.42
MOIST 13.0
FIBER 4.30
FAT 5.0
HOMINY FEED
PROT. 8.4
ASH 1.14
MOIST. 15.5
FIBER 2.10
FAT 3.7
RAW CORN
PROT. 7.5
ASH .29
MOIST. 14.0
FIBER .58
FAT 0.6
CEREAL GRITS
PROT. 14.5
ASH 4.6
MOIST. 2.5
FIBER 4.5
FAT 20.7
GERM
WASHING & SCRUBBING
TEMPERING BIN
DEGERMERS
ASPIRATORS
SIFTERS
ROLLER MILLS
ASPIRATORS
COOLERS
DRYERS
PROT 7.7
ASH .22
MOIST. 15.5
FIBER .75
FAT 0.7
BREWERS GRITS
THRU-STOCK
PROT. 7.3
ASH 0.13
MOIST. 12.5
FIBER .57
FAT 0.7
CORN MEAL
DRYERS
COOLERS
ASPIRATORS
ROLLER MILLS
SIFTERS
SPECIALTY MILL
HOMINY STOCK
PROT. 6.0
ASH .30
MOIST 12.0
FIBER .59
FAT 0.8
CORN CONES
BINDER FLOURS
SPECIALTY PRODUCTS
PROT. 7.5
ASH .30
MOIST 6.0
FIBER .5
FAT .8
PROT. 8.0
ASH .30
MOIST 9.0
FIBER .5
FAT 0.8
PROT. 6.0
ASH .40
MOIST 12.5
FIBER .81
FAT 1.4
COREBINDER
BREWERS FLAKES
CORN FLOUR

FIGURE -- 15

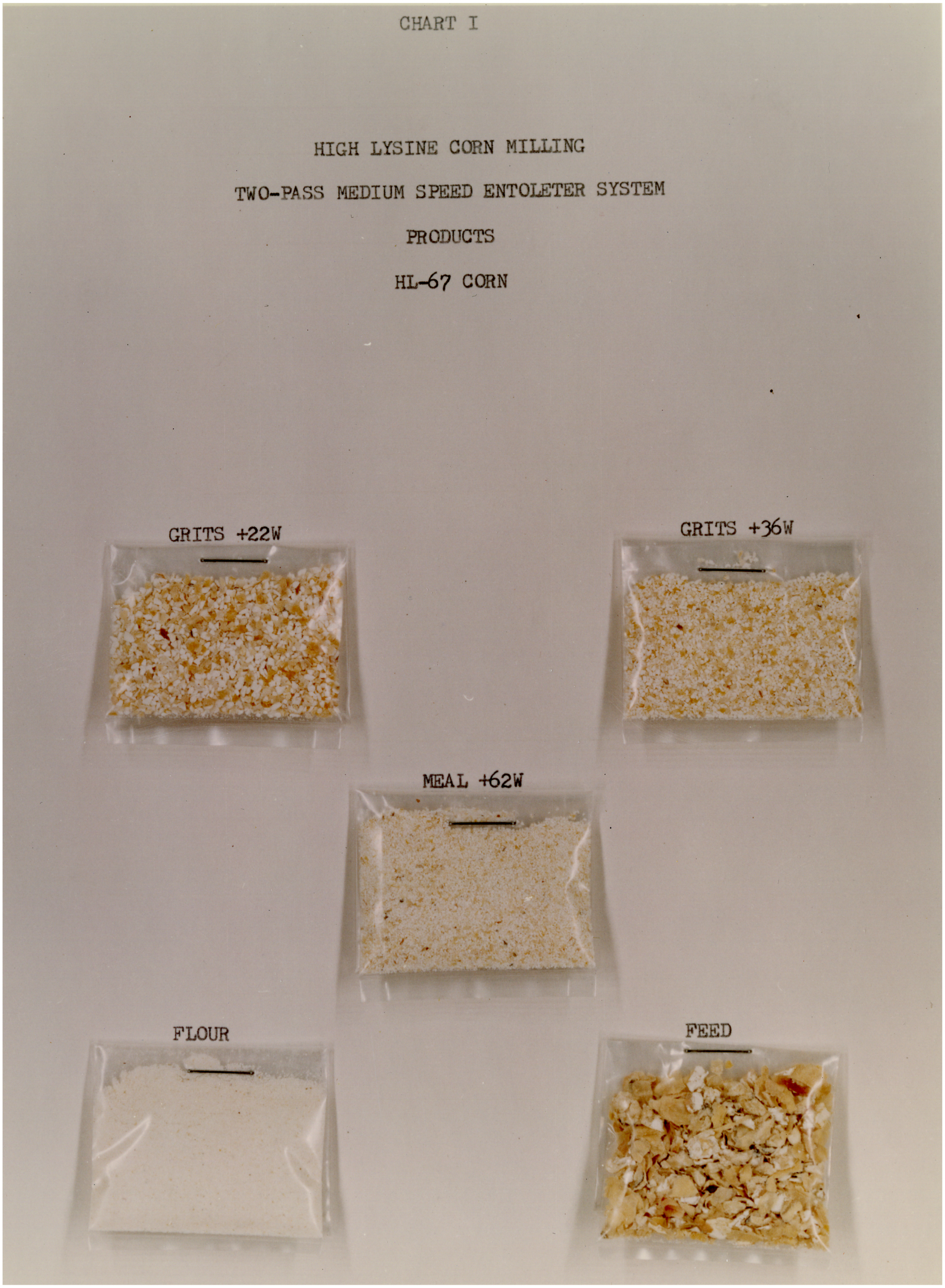


CHART I
HIGH LYSINE CORN MILLING
TWO-PASS MEDIUM SPEED ENTOLETER SYSTEM
PRODUCTS
HL-67 CORN
GRITS +22W
GRITS +36W
MEAL +62W
FLOUR
FEED

N214-3


CHART II
HIGH LYSINE CORN MILLING
ONE-PASS HIGH SPEED ENTOLETER SYSTEM
PRODUCTS
HL-67 CORN
GRITS +22W
GRITS +36W
MEAL +62W
FLOUR
BRAN
GERM
TAILINGS

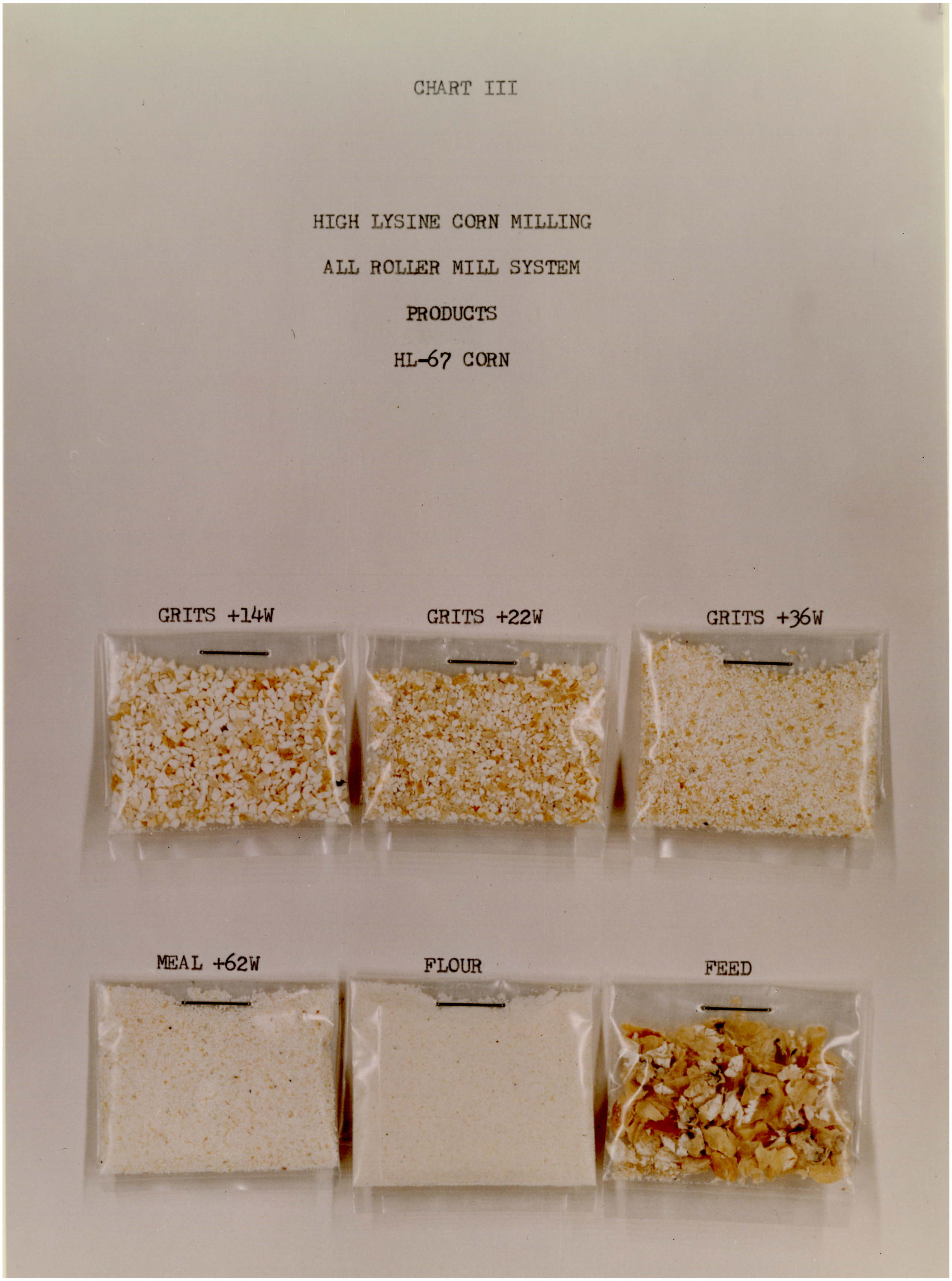


CHART III
HIGH LYSINE CORN MILLING
ALL ROLLER MILL SYSTEM
PRODUCTS
HL-67 CORN
GRITS +14W
GRITS +22W
GRITS +36W
MEAL +62W
FLOUR
FEED

N 214-1

CONCLUSIONS

Dry milling characteristics of high lysine corn, as determined by milling in the Entoleter-roller mill system, were improved by use of a short second temper prior to degermination. The use of a second temper lowered the attached hull count, improved germ release and also proved most beneficial in the yield of total endosperm.

The effectiveness of the second temper was also influenced by the rotor speed of the Entoleter degerminator. Appreciable differences were noted in degree of degermination obtained and yield of flour. The Entoleter degerminator samples appeared best. In the all roller mill degermination some germ was ground into fine particles. As a result, oil recovery into feed was lowered and the oil content of the flour fraction was almost twice that of the flour from the one-pass high speed Entoleter degermination.

Comparing the three types of degerminating systems used, the one-pass high speed Entoleter was best, the two-pass medium speed Entoleter second and the all roller mill last.

From the evidence of the present work, the following recommendations are made for the most efficient separation of products of the highest quality and yield, while using an Entoleter degerminator ahead of the break system in a corn milling plant for high lysine corn.

1. High lysine corn should be tempered to about 16-17% moisture content at least 3 hrs. followed by a second temper to 21-22% moisture about 15 minutes prior to degermination.
2. The Entoleter degerminator should be fitted to degerminate corn and should be of variable speed to handle the different types of corn and control the amount of reduction.

Since floury corn is soft and the endosperm is very friable, these characteristics permit easy grinding of the corn into flour, by no means any of the present milling systems of dry milling corn will produce flaking grits from high lysine corn. Perhaps the old criterion about dry milling common corn should be changed to accommodate the floury corns, which are very important in present days.

The possibility of a shorter system is also suggested by the One-Pass High Speed Entoleter System.

ACKNOWLEDGMENTS

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NEW METHODS OF DRY MILLING AND HIGH LYSINE CORN

by

RODOLFO VIVEROS OLAVARRI

B. S., Lewis College of Science and Technology, 1955

Lockport, Illinois

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

High lysine corn (12-13% moisture) from a single lot, tempered at room temperature, was degerminated and subsequently milled by each of three systems.

1. Conventional roller-mill system.
2. Two-pass medium speed Entoleter system.
3. One-pass high speed Entoleter system.

High lysine corn is a floury corn with a soft and friable endosperm. Degermination and subsequent roller milling of high lysine corn was moderate to good for each system. Although the conventional all roller-mill system gave the highest production of -10 +14 grits (not shown in the data), the other two systems gave the best yield of total endosperm.

Results show that any system can be used, the choice depends on the available equipment and separation of products required.

The one-pass high speed Entoleter degermination system gave the maximum yield of flour of lowest fat content and feed of the highest fat content.

Addition of a second temper increased hull release, and lowered the fat content and yield of -14 and +22 grits.

High release of flour came with the highest rotor speed (4000 vs 2000 r.p.m.) but reduced yields of +22 grits.

From the data presented, which should be of use to those working for improved degermination and dehulling, the possibility of a shorter Entoleter-roller mill system is suggested.