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THE EFFECTS OF THE FIRST BREAK ROLLER MILL DIFFERENTIALS AND SPEEDS

by

Noritaka Tsuge

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Department of Grain Science and Industry

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Major Professor

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Introduction

Many investigators or millers have made great efforts to find the optimum setting of roll differentials, corrugations, spirals, speeds, etc., ever since pairs of iron rollers were introduced to the modern milling. Although these settings vary somewhat among mills, the range of their variation is limited.

The object of this study is to find how the differentials and roll speeds on the first break influence the characteristics of the middlings extracted from the first and second break grindings and which differential or speed gives the best results for subsequent milling processes.

The purpose of white flour milling is to separate the bran and germ from the endosperm and convert the endosperm into fine flour particles. The first stage of a flour milling process is the break system, in which wheat kernels are opened up and the endosperm is released. Over the years the best way to open up wheat kernels has been to pass them through a series of pairs of spirally corrugated rolls driven at different speeds. In the first break sifter the portion broken off, consisting of particles below a definite size limit, passes through the wire mesh of the scalping sieves. The tailover of these sieves forms the feed for the second break rolls. At this and succeeding stages, the procedure is repeated, each set of rolls having a greater number of corrugations per circumferential inch and having closer grinding gaps than the rolls of the preceding break. This is necessary because of the gradually diminishing thickness of the endosperm layer remaining attached to the bran flakes.

The purpose of the break system is to produce the greatest possible amount of chunks of the endosperm, called middlings, with the least possible amount of attached bran. Therefore, in the break system, a relatively small amount of flour, the finest part of the fractions sifted, is produced. Middlings separated in the break system are fed to the reduction rolls in which the bulk of the flour is produced. In order for the reduction system to perform its task in the best manner, it is necessary that the middling stocks at the head of the reduction system be ss free from bran ss possible. The removal of small bran chips by purification of the middling, however, largely depends on the performance of the break system.

Review of The Literature

The first break rolls are an initial process of white flour milling. Therefore, they are generally looked upon as the most important process in a flow diagram. All wheats to be milled pass through them and are broken into a mixture of particles; mainly bran coats which are still thickly coated with endosperm, middlings, and a small amount of fine flour. After being separated by size, each fraction is distributed to subsequent stages; such as the second break rolls, purifiers, sizing system, and reduction system. For this reason, the first break process controls the entire flow diagram. Not only the quantity of each fraction, but also their ash and protein contents affect the characteristics of flour made in subsequent stages. The characteristics of the first break fractions are affected by various factors; such as wheat variety, hardness, ash and protein contents, tempering, feed rate, extraction percentage, roll spirals, corrugations, differentials, and roll speeds. Some of these will be discussed in the following sections.

I. Characteristics of flour streams.

A. Ash distribution.

Ash content is widely used as an indicator of the degree of freedom of a milled stock from bran materials. Generally speaking, the lower the ash content of flour the higher the grade of flour.

Morris <u>et al.</u> (12) investigated the distribution of ash in a wheat kernel and reported that the lowest concentration of ash was found in the "cheek endosperm" fraction of varieties tested and that the concentration of ash in the peripheral zone was considerably greater than in the cheek or center fractions. It is generally recognized that the ash content increases from the center section to the peripheral section in a whest kernel and that the ash content of bran is 10 to 20 times that of the center section. Therefore, the incorporation of a relatively small qusntity of bran particles will result in s considerable increase in ash content.

Swanson(23) pointed out three causes of high ash in flour:

1. Some fsults in the mechsnical operstion of the mill, either cleaning the wheat, tempering, or grinding with subsequent sepsration.

2. Uae of wheat which has a high ssh in the endosperm.

3. The presence of damaged whest in the mill mix.

In other worda, when milling the ssme wheat, a high ash content in the flour is sttributed to some faults in the mechanicsl operstion of s mill which will cause the incorporation of bran particles.

B. Protein distribution.

Protein is important for wheat flour milling in respect to its functionality in bresd production and its nutritional property. High protein flour ia used for bread and low protein flour is used for cake and cookie baking. Protein content in wheat kernels depends on both variety snd fertilizer application rates(30).

Morris et sl. (12) reported that the pattern of the distribution of protein in the various fractions was much the same aa for ash. Hia reaults supported the ides of an increasing gradient in the concentrstion of protein from the center of the endosperm to the bran coat.

Ziegler et sl. (29) reported that protein content generally rose progressively from the first to the last break flour, in keeping with the gradient in the endoaperm, the steepness of the rise, and the relative level of the bresk flours as a group; snd that in the reduction system, protein content was generally low in the hesd reduction flours and rose toward the end of the reduction system.

Tipplea <u>et al.</u> (24) investigated the quality characteristics of flour streams milled from Canadian hard red spring wheat. According to their results, the samples ranged widely in protein content from 11.5% to 19.2%. When compared to the reduction flours, the break floura were characterized by higher protein content, lower damaged starch, atronger dough characteristics, larger volume, and higher baking absorption.

II. Break system.

The break aystem controls the entire flow of a mill stream and helps the reduction system produce the maximum amount of flour with the minimum ash content from given wheata. It is not an important task for the break aystem to produce flour. Neal(13) stated "The subject of the separations made on your breaka has a great bearing on the quality of the product you are endeavoring to produce. There ia the atarting point. There is where you have to make your claasificationa in order to keep your mill properly balanced."

A. Wheat conditioning.

Wheat milling ia possible because the endosperm is a little more brittle than the bran and germ. The main purpose of wheat conditioning is to enhance the brittleness of the endosperm and to toughen the bran by making water penetrate wheat kernels thoroughly during a given rest period.

Corkrum(3) reported that too dry a wheat could raise the ash and alao affected the protein.

Wichaer <u>et al.</u> (28) investigated the influence of the length of tempering period, the amount of tempering water, and heat conditioning. According to their reaulta, the length of tempering period, ranging from 4 to 48 hours, had no influence on flour extraction, ash and protein contents, mixogram curve or farinograph, or baking results and little influence on the granulation of flour. The amount of tempering water affected the flour extrsction rates which were reduced from 72% obtained from the 16% moisture tempered wheat to 66% and 64% respectively obtained from the 12% and 20% moisture tempered wheats. Heat conditioning at 120^{o}F had no influence on granulation, ash and protein contents, fsrinograph absorption, mixograph, snd baking results.

Pence(19) reported thst the use of steam, within the limits used in his work, did not affect any properties of flour produced, but could reduce the rest period, if the wheat was properly cooled before entering the tempering bins.

Tipples et al. (25) investigated the influences of increasing the tempering moisture from 14.5% to 17.5% on the first break grinding and the following results were obtained:

1. Flour yield decreased slightly.

2. Fine fraction was relatively constant.

3. Medium fraction increased slightly.

4. Cosrse fraction incressed significantly.

5. Overtail decreased steadily.

6. Ash contents of all streams except for overtail decreased steadily and significantly due to more toughened bran by more amount of water.

7. The pattern of protein content change was similar to that of ash content change but to a lesser degree.

B. Pre-breaking.

According to the report of Wingfield(27), more than hslf of the mills in the United States use the pre-breaking system. Of these using the pre-breaking system, 60% use roller mills ss pre-breaking machines.

The A.O.M. Technical Committee(8) reviewed the specifics of the pre-breaking system and reported the following percentages of preference:

1. Roll surface	smooth	30%
	40 corr./inch	35%
	10 corr./inch	35%
2. Differentisl	1:1	70%
	1.25:1	30%
3. Circumferentisl speed of fsst roll	1150 to 1299 ft./min.	

Curran(5) documented the effects of pre-breaking of whest kernels prior to the actual milling process using several experimental mills, including the Kansas State University pilot flour mill with a capacity of 200cwt/day. His results indicsted thst, if properly applied, the pre-break system might aid in providing flours both at lower ssh contenta and at somewhat higher extractions. He slso pointed out the beneficisl effect of aifting of the pre-broken wheat before the actual milling. Flour obtsined from test milling where the pre-broken stock was sifted before the actual milling was found to be slightly lower in ssh than when the pre-break was used without sifting.

In spite of these advantages of the pre-breaking operation, the pre-break system is not used in Jspsn. The reason for this is to shorten the roll length snd thereby reduce power usage. Jspsnese millers, however, recognize the beneficisl sdvantages of the pre-bresking system. Therefore, some factories tend to open the hesd of the break roll system to improve the flour color or yield.

C. Roll speeds.

Typicsl circumferential speeds of the fast roll used by the U.S. mills are reported below by percent of mills(8):

First and second breaka	1300 to 1499 ft./min. 1500 to 1699 ft./min.	45% 30%
Third break	1150 to 1299 ft./min. 1300 to 1499 ft./min. 1500 to 1699 ft./min.	30% 30% 30%
Fourth and fifth breaks	1150 to 1299 ft./min. 1300 to 1499 ft./min. 1500 to 1699 ft./min.	30% 30% 40%

Henry(10) suggested the following RPMs with the approximately same circumferential faat roll speed of 1178 ft./min.:

10" diameter rolls ------- 350 to 450 RPM

9" diameter rolls ------- 450 to 550 RPM

7" diameter rolls ------- 550 to 650 RPM

Tipples et al. (25) tested the influences of increasing roll apeed from 150 RPM to 300 RPM on the slow roll when the roll differential and feed rate were held conatant. The coarse fraction increased alightly, the ash contenta of the flour, medium, and fine fractiona increased, and the protein contents of all fractions, except for the overtail, also increased. These changes in chemical components were explained by the increased scalping action which released more endosperm cells from the peripheral area where the cells were higher in protein and aah than in the center area. However, these effects of roll speed were relatively small.

Niernberger(14) investigated the effects of roll speed on the first break grinding and concluded that roll speed would not significantly affect the first break operation.

D. Differentials.

All pairs of rolls, except for pre-break rolla, are driven at different speeds. Rolls driven at faster speed are called the cutting or shearing rolls, whereas rolla driven at slower speed are called the holding rolls. Differential contributes its share of shearing and the greater the differential the greater the shearing. Shearing action is necessary for the separation of the endosperm from the bran coat and for diminishing the particle size of middlings.

Differentials on break rolls, with few exceptions, run at 2.5:1(10)(11)(17)(18). Jurkow(11) stated "A differential speed ratio of 2.5:1 has been found by experience to give the best average performance." Pence(17) stated "When the roller mills were first introduced, it was found by careful experimenting and close observing that a 2.5:1 differential gave good results."

Pence(17) also tested which differential produced the maximum amount of middlings or the cleanest middlings under the condition of a constant roll clearance. Five differentials of 1.5:1, 2.0:1, 2.5:1, 3.0:1, and 3.5:1 were used in his experiment. A differential of 1.5:1 produced the cleanest middlings but the amount of middlings produced was not enough. A differential of 2.5:1 produced the most satisfactory middlings and the increase in the differential from 2.5:1 resulted in the increase in the ash content of middlings produced.

Tipples et al. (25) conducted a similar experiment and reported that the higher the differential, the higher the amount of middlings produced and ash and protein contents due to the increase in the shearing and scraping actions with higher differentials. They also measured the damaged starch of flour and got the same increasing trend as with the ash and protein contents.

Oliver et al. (15) tested the effects of five differentials between 2.0:1 and 5.0:1 with a constant roll clearance. In addition to obtaining the same results as Pence and Tipples did, he suggested that higher differentials saved power consumption but resulted in poorer dough quality.

In the modern milling industry, almost all flour mills are controlled by a fixed extraction rate on each break. These tests should be conducted under the condition of a fixed extraction rste instead of a constsnt roll clearsnce.

E. Roll diameters.

It has been known that roll diameter has an influence on grinding action.

Roll diameters most widely used are 9" and 10" (250 mm) although rollers with a dismeter of 12" (300 mm) are sometimes used for the hesd part of the reduction system(4)(8).

Creason(4) stated "We are safe in saying that the larger diameter rolls with a greater arc of contact would be better on the coarse reduction, the smaller dismeter rolls with less arc of contact on the lower reduction." As Pence(17) pointed out, it is obvious that the greater the diameter, the greater the grinding zone and residence time when a roll clesrsnce is held constsnt. This fact affects the manner of actions of the angle snd number of corrugations on break rolls.

Niernberger(14) reported the effects of roll diameter on ash content and particle size of the product from the first bresk rolls with sll other factors constant. His results indicsted that bresk rolls with 9" diameter gave the most satisfactory results in the first break grinding with a 2.5:1 differential.

F. Extraction rate.

The chsracteristics of frsctions extracted from the head psrt of the bresk system are importsnt for further grindings in the reduction system, as Wingfield(26) stated "In setting the first bresk extraction, you directly affect 33 percent of the flour being made."

Pence(18) defined "fixed extraction" ss the setting of a pair of rolls making a given amount of middlings and regarded it as one of the most important means to keep a mill balanced and to insure uniformity of the finished product. The distance between rolls, called roll gap or clearance, does not mean anything. The following factors having an influence on the extraction were pointed out(18):

1. The type and condition of grain.
2. The distance between rolls.
3. The amount of pressure maintained on the tension spring.
4. The humidity and temperature of the room.

Feese(7) stated that feed rate also had an influence on the extraction rate.

Jurkow(11) stated "An optimum extraction that will work out to best advantage is determined by trial and experiment and once it is decided upon, it should be strictly adhered to."

Robbins(21) conducted an experiment using coarse, medium, and fine roll settings on each break, first through third. Samples were ground with various combinations of these settings, resulting in 27 combinations. According to his results, the nature, quality, snd size distribution of the stocks extracted from break rolls had a marked influence on the entire milling process and affected ash and protein distributions and the baking characteristics of the various flour streams. The total first, second, and third break extraction was influenced by the extractions of the different breaks but the total tended to vary over a limited range. The first break provided uniform particle size distribution. The second break provided a comparatively small amount of large sized and a large amount of medium and fine sized stocks and was largely responsible for variations in particle size distribution in the total first, second, snd third break extraction.

Wichser et al. (28) conducted an experiment wherein the amount of break release on the first, second, and third breaks was varied with the total break release of the three breaks being held constant. They reported that varying the amount of break release on the aecond and third break stocks had little effect on the granulation of the resulting straight grade flour. On the first break, a break release of 30% or leaa had no effect. A break release of greater than 30%, however, produced some flour granulation differences.

Peterson(20) varied the first and second break extractiona with the total break release being held constant. In the test with 20% of release on the first break, 0.60 lbs of aah waa released by the first three breaks for each one hundred lba of wheat going to the first break. In the test with 30% of releaae on the first break, 0.67 lbs of ash was released. He stated "In general, it has been our experience that open first break grinding produces better grade flour than close first break grinding." Gabbert(9) supported Peterson's result that open setting on the firat break enabled millers to get more patent flour.

However, 30% of release on the first break and 40% on the second break were shown aa an average releaae on each break by some investigators (6)(10)(16). Jurkow(11) atated that the tendency had been more toward higher extractions at the head, tapering off gradually toward the tail of the system. The reason for this was that by doing a greater share of the work with the coarse corrugations of the head breaks, a proportionally greater amount of the total extraction would consist of large well-shaped middlings and lesa of it would be in the form of break flour and fine middlings.

G. Corrugations.

Cleve et al. (2) investigated and reported the differences in cumulative aah curves of the first break grindings tested with three corrugations.

Schumacher(22) stated that the grinding effect of the rollers was accomplished by their impact, scraping, cutting, and shearing. The impact was determined by the angle of the corrugations and the difference in peripheral speed of the rolls. The scraping and cutting actions were mainly influenced by the type of corrugations and the greater the spiral, the greater the shear.

The typical corrugations used in the United States are (4)(8)(10):

10-14 corr./inch	on the first break.
12-16 corr./inch	on the second break.
14-20 corr./inch	on the third break.

The numbers shown above vary between the range and depend on the number of break rolls used. Break aystems consisting of 5 break rolls are most widely used.

Break rolls are in nearly all caaes run "dull to dull" in the United States; that is, with the long side on the fast roll corrugation facing the long side of the corrugation on the slow roll(11)(27).

H. Hardness of Wheat.

Blakeney et al. (1) investigated the differences in the breakage pattern on the first break grinding between soft and hard wheats. The hard wheat was seen to shatter into large regular piecea with little release of fine particles; the soft wheat was deformed and then burst into many fine particles. The average residence times for the hard and soft wheats were 0.0088 and 0.010 seconds reapectively. The reason given for this difference ia that the air apace within the endoaperm of the soft wheat may act aa an air cushion, allowing the grain to deform but alao transmitting the applied crushing force hydrostatiatically throughout the endosperm.

Materials and Methods

Hard red winter wheat was used in this experiment. This wheat was subjected to laboratory analysis prior to experimental grinding. The specifications of the wheat used are shown in Table 1.

The wheat was cleaned by passing it through the cleaning system of the Kansas State University pilot flour mill and conditioned by raising the moisture content to 16 percent. A 20 hour rest period at room temperature in sealed metal cans allowed water to penetrate the wheat kernels thoroughly. The moisture addition was facilitated by using a rotating metal drum to evenly distribute the water.

The flow sheet used is shown in Figure 1. This flow diagram consisted of two break roll sets, first and second break rolls. The first break rolls were 6" in diameter and 6" in length. The second break rolls were 9" in diameter and 6" in length. The corrugations are shown on the flow sheet.

The first break differentials used in this experiment were 2.0:1, 2.5:1, and 3.0:1. The first break roll speeds selected for this experiment were classified into fast, medium, and slow speeds. The speeds were 670, 530, and 370 RPM on the fast roll of the first break rolls respectively. Roll speed and differential on the second break rolls were kept constant through this experiment. All of these roll speeds and differentials were also shown in Figure 1.

The feeding rate of tempered wheat was adjusted to 1 lb./minute/inch and kept constant through this experiment.

The extraction rates for the first and second break rolls were 30 and 40 percent respectively. After an initial roll warming-up period, roll clearance was set to extract 30 percent of fine produce through a number 20 Light Wire sieve with 1041 micron opening. A 40 percent break extraction on the second break was obtained in the same way as on the first break.

Products passing through the rolls were sifted in a Great Western laboratory sifter and the various fractions were weighed after each operation. The openings of the sieves used are shown in Figure 1.

The weights of the various fractions were then converted to percent release and then to percent extraction. These results are shown in Tables 2 to 10.

A sufficient quantity of each fraction was obtained for laboratory analysis of moisture, ash, and protein contents.

Table 1.

WHEAT SPECIFICATIONS

TEST	RESULTS [1]
Moisture[2]	9.9%
Protein[3]	10.1%
Ash[4]	1.62%
Test weight[5]	62.6 lbs/bushel
1000 Kernel Weight[6]	29.7 gram/1000 kernels
Wheat Size[7]	
+7W	58.5%
+9W	40.7%
+12W	0.8%
Pearling Value[8]	72.9%

1. Results given are the average of two analyses.

2. AACC Approved Methods, 44-19.

3. AACC Approved Methods, 46-10. (14% moisture basis)

4. AACC Approved Methods, 08-01. (14% moisture basis)

5. As described in Circular No. 921, issued by the United States Department of Agriculture.

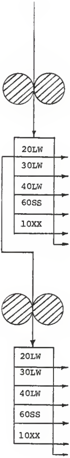
6. 40 grams of whole, cleaned wheat is counted by using an electronic seed counter. The number of kernels in 40 grams is then converted to the number of grams per 1000 kernels.

7. 200 grams of cleaned wheat is sifted for 1 minute by using a Ro-Tap Shaker and 3 Tyler sieves of 7 wire, 9 wire and 12 wire. The percentage remaining on each sieve is then determined.

8. 20 grams of cleaned, whole wheat is retained for one minute in a Strong Scott Laboratory Barley Pearler equipped with a No. 30 grit stone and 1 10 mesh screen made of wire .041 inches in diameter. Pearling value is the percent of original sample remaining over a 20 mesh wire after pearling.

Figure 1

FLOW SHEET



Wheat	Hard Red Winter
Tempering	
Moisture	16%
Period	20 hrs
First Break	
Differentials	2.0:1, 2.5:1, 3.0:1
Speeds (fast)	370, 530, 670 RPM
Corrugation	12/12 G D:D
Release	30%
Feed Rate	1 lb./min./inch
Dia. x Length	6" x 6"
Second Break	
Differential	2.5:1
Speed (fast)	320 RPM
Corrugation	12/14 G D"D
Release	40%
Dia. x Length	9" x 6"

Results and Discussion

Chemical analysis results are shown in Tsbles 2 to 10 with the extraction and release rates.

I. Cumulative ash and protein curve analysis.

A. Cumulative ash curves.

The cumulative ash curves of the first break fractions are shown in Figures 2 to 4./(See appendix for the cumulative ash calculations.) These curves were plotted in the increasing order of the sieve opening size. These figures indicate the trends that the larger the differential, the higher the cumulative ash contents in finer fractions; and that the final cumulative ash contents of the first break fractions ground with a differential of 2.5:1 were always lowest. This latter trend indicates that the first break with a differential of 2.5:1 presents cleaner farina to coarse middling rolls or purifiers than those with the other differentials.

Figures 5 to 7 show the cumulative ash curves of the second break fractions. The trends discussed above were not recognized in these curves.

Figures 8 to 10 show the cumulative ash curves of the combined first and second break fractions. The patterns found in the cumulative ash curves of the first break were recognized in these cumulative ash curves.

B. Cumulative protein curves.

The cumulative protein curves of the first, second, and combined first and second break fractions were plotted in Figures 11 to 19 in the same order as the cumulative ash curves.

In Figures 11 to 13 for the first break fractions, a

Table 2.

Granulation and laboratory analysis results

for a 2.0:1 differential and a 370 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.7	70.7	10.8	2.04
	+30LW	10.7	10.7	8.7	0.91
	+40LW	5.8	5.8	8.0	0.51
	+60SS	4.6	4.6	8.0	0.44
	+10XX	6.1	6.1	8.0	0.37
	-10XX	2.2	2.2	8.1	0.37
2nd Break	+20LW	59.6	42.1	12.5	3.08
	+30LW	10.5	7.4	10.5	1.42
	+40LW	10.3	7.3	9.1	0.41
	+60SS	7.9	5.6	9.2	0.34
	+10XX	8.4	5.9	8.9	0.32
	-10XX	3.4	2.4	9.0	0.35

* ——— 14% Moisture Basis

Table 3.

Granulation and laboratory analysis results

for a 2.5:1 differential and a 370 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	69.9	69.9	10.8	2.06
	+30LW	11.1	11.1	8.7	0.83
	+40LW	6.0	6.0	8.2	0.52
	+60SS	4.8	4.8	8.1	0.44
	+10XX	6.1	6.1	8.2	0.39
	-10XX	2.2	2.2	8.0	0.37
2nd Break	+20LW	60.1	42.0	12.4	3.05
	+30LW	10.5	7.3	10.4	1.32
	+40LW	10.2	7.1	8.9	0.39
	+60SS	7.8	5.5	9.3	0.36
	+10XX	8.1	5.7	8.9	0.33
	-10XX	3.2	2.2	9.0	0.35

* ——— 14% Moisture Basis

Table 4.

Granulation and laboratory analysis results

for a 3.0:1 differential and a 370 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.8	70.8	11.2	2.04
	+30LW	10.8	10.8	8.4	0.86
	+40LW	5.7	5.7	8.2	0.56
	+60SS	4.6	4.6	8.1	0.46
	+10XX	5.9	5.9	8.2	0.42
	-10XX	2.1	2.1	8.2	0.40
2nd Break	+20LW	58.6	41.4	12.3	3.06
	+30LW	10.7	7.6	10.2	1.42
	+40LW	10.7	7.6	9.1	0.40
	+60SS	8.2	5.8	9.3	0.34
	+10XX	8.4	5.9	9.1	0.32
	-10XX	3.4	2.4	8.7	0.37

* ——— 14% Moisture Basis

Table 5.

Granulation and laboratory analysis results

for a 2.0:1 differential and a 530 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	71.1	71.1	11.2	2.04
	+30LW	10.7	10.7	8.8	0.95
	+40LW	5.7	5.7	8.1	0.54
	+60SS	4.6	4.6	8.1	0.45
	+10XX	5.8	5.8	8.2	0.38
	-10XX	2.1	2.1	8.0	0.38
2nd Break	+20LW	60.0	42.7	12.2	2.95
	+30LW	10.8	7.7	10.2	1.53
	+40LW	10.5	7.5	9.0	0.43
	+60SS	7.7	5.5	9.4	0.36
	+10XX	8.0	5.7	9.0	0.34
	-10XX	3.1	2.2	8.9	0.37

* ——— 14% Moisture Basis

Table 6.

Granulation and laboratory analysis results

for a 2.5:1 differential and a 530 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.7	70.7	11.0	2.04
	+30LW	10.7	10.7	8.7	0.88
	+40LW	5.9	5.9	8.0	0.52
	+60SS	4.7	4.7	8.1	0.45
	+10XX	5.9	5.9	8.2	0.39
	-10XX	2.1	2.1	8.1	0.40
2nd Break	+20LW	59.9	42.3	12.3	3.07
	+30LW	10.5	7.4	10.3	1.33
	+40LW	10.5	7.4	8.9	0.39
	+60SS	7.9	5.5	9.3	0.35
	+10XX	8.1	5.7	9.0	0.34
	-10XX	3.2	2.3	8.8	0.37

* ——— 14% Moisture Basis

Table 7.

Granulation and laboratory analysis results

for a 3.0:1 differential and a 530 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.8	70.8	11.4	2.05
	+30LW	10.6	10.6	8.4	0.90
	+40LW	5.9	5.9	8.2	0.53
	+60SS	4.7	4.7	8.2	0.48
	+10XX	5.9	5.9	8.3	0.43
	-10XX	2.2	2.2	8.1	0.43
2nd Break	+20LW	59.7	42.3	12.4	3.08
	+30LW	10.4	7.4	10.6	1.43
	+40LW	10.6	7.5	9.0	0.41
	+60SS	7.9	5.6	9.3	0.35
	+10XX	8.1	5.7	9.0	0.34
	-10XX	3.2	2.3	9.0	0.38

* ——— 14% Moisture Basis

Table 8.

Granulation and laboratory analysis results

for a 2.0:1 differential and a 670 RPM.

Break	Meah	Releaae (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	71.3	71.3	11.2	2.04
	+30LW	10.6	10.6	8.5	0.92
	+40LW	5.8	5.8	8.2	0.52
	+60SS	4.6	4.6	8.0	0.43
	+10XX	5.8	5.8	8.0	0.38
	-10XX	2.0	2.0	7.9	0.39
2nd Break	+20LW	60.3	43.0	12.5	2.97
	+30LW	10.3	7.3	10.9	1.33
	+40LW	10.4	7.4	9.1	0.54
	+60SS	7.7	5.5	9.3	0.36
	+10XX	8.2	5.8	9.1	0.34
	-10XX	3.1	2.2	9.0	0.37

* ——— 14% Moiature Baaia

Table 9.

Granulation and laboratory analysis results

for a 2.5:1 differential and a 670 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.5	70.5	11.5	2.06
	+30LW	11.0	11.0	8.7	0.79
	+40LW	6.0	6.0	8.2	0.53
	+60SS	4.7	4.7	8.2	0.44
	+10XX	5.9	5.9	8.1	0.40
	-10XX	2.0	2.0	7.9	0.40
2nd Break	+20LW	60.9	42.9	12.4	3.07
	+30LW	10.2	7.2	10.4	1.32
	+40LW	10.2	7.2	9.1	0.40
	+60SS	7.7	5.4	9.2	0.35
	+10XX	8.2	5.8	9.0	0.33
	-10XX	3.0	2.1	8.8	0.36

* ——— 14% Moisture Basis

Table 10.

Granulation and laboratory analysis results

for a 3.0:1 differential and a 670 RPM.

Break	Mesh	Release (%)	Extraction (%)	Protein* (%)	Ash* (%)
1st Break	+20LW	70.7	70.7	11.4	2.06
	+30LW	10.9	10.9	8.5	0.87
	+40LW	5.9	5.9	8.0	0.53
	+60SS	4.5	4.5	8.1	0.45
	+10XX	5.9	5.9	8.2	0.43
	-10XX	2.1	2.1	8.2	0.43
2nd Break	+20LW	60.5	42.8	12.3	3.09
	+30LW	10.1	7.1	10.3	1.43
	+40LW	10.3	7.3	9.1	0.43
	+60SS	7.8	5.5	8.9	0.37
	+10XX	8.2	5.8	9.0	0.33
	-10XX	3.0	2.1	8.8	0.39

* ——— 14% Moisture Basis

Figure 2. Cumulative ash curves of the first break for a roll speed of 370 RPM.

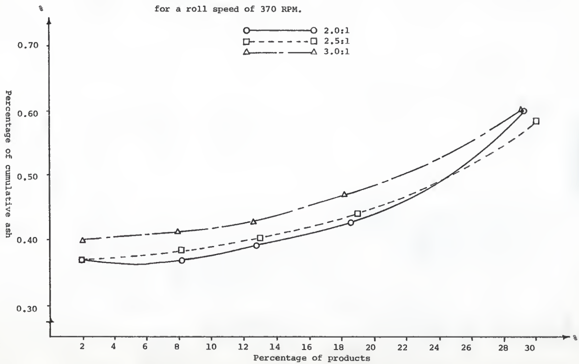


Figure 3. Cumulative ash curves of the first break for a roll speed of 530 RPM.

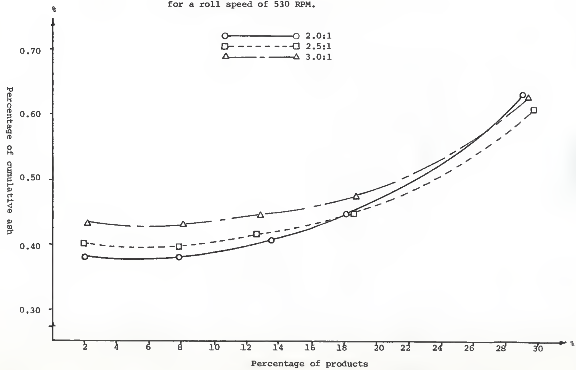


Figure 4. Cumulative ash curves of the first break for a roll speed of 670 RPM.

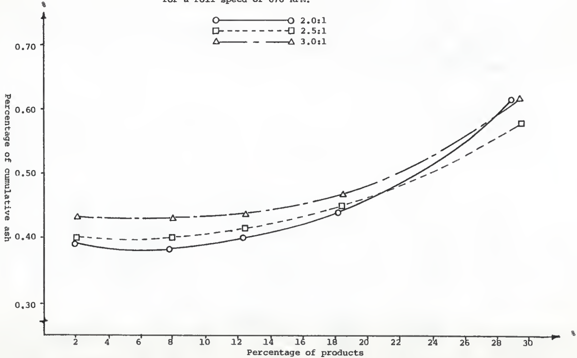


Figure 5. Cumulative ash curves of the second break for a first break roll speed of 370 RPM.

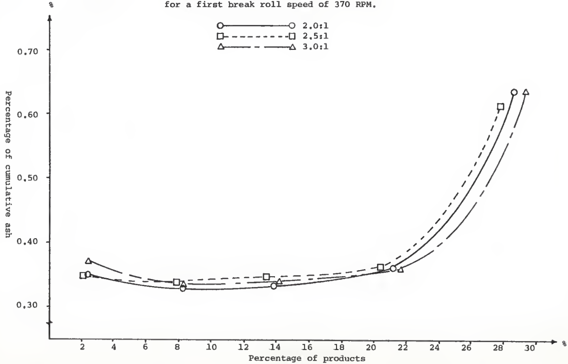


Figure 6. Cumulative ash curves of the second break for a first break roll speed of 530 RPM.

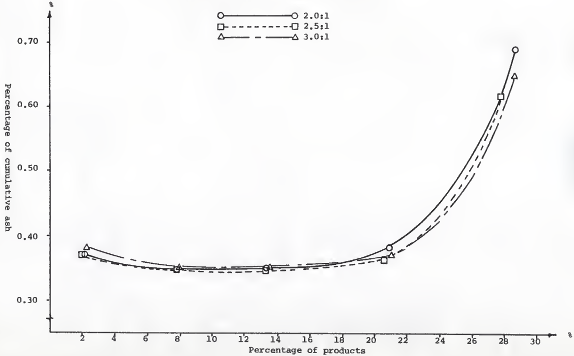


Figure 7. Cumulative ash curves of the second break for a first break roll speed of 670 RPM.

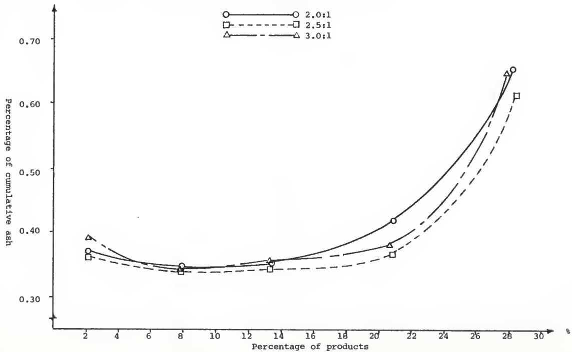


Figure 8. Cumulative ash curves of the combined first and second break for a first break roll speed of 370 RPM.

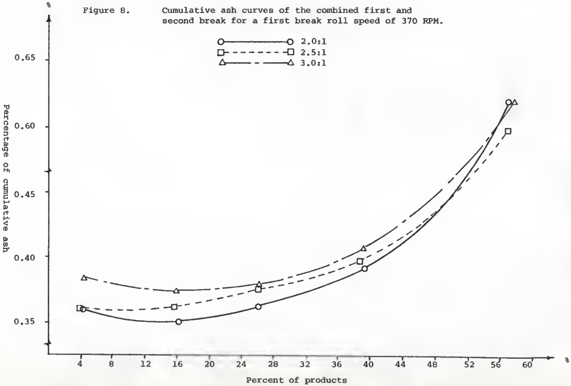
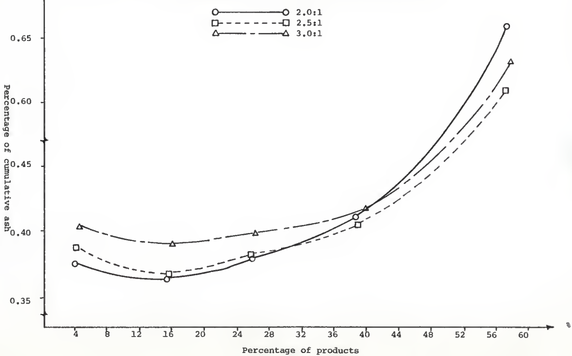


Figure 9. Cumulative ash curves of the combined first and second break for a first break roll speed of 530 RPM.



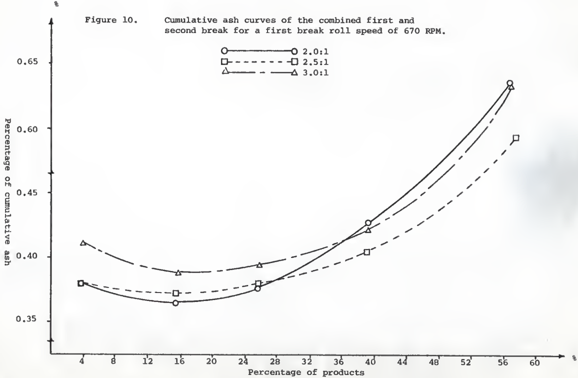


Figure 10. Cumulative ash curves of the combined first and second break for a first break roll speed of 670 RPM.

Figure 11. Cumulative protein curves of the first break for a roll speed of 370 RPM.

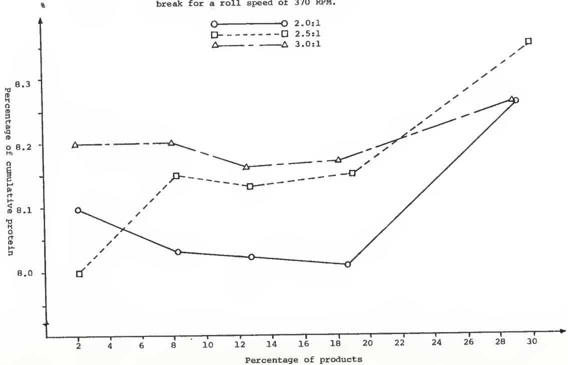


Figure 12. Cumulative protein curves of the first break for a roll speed of 530 RPM.

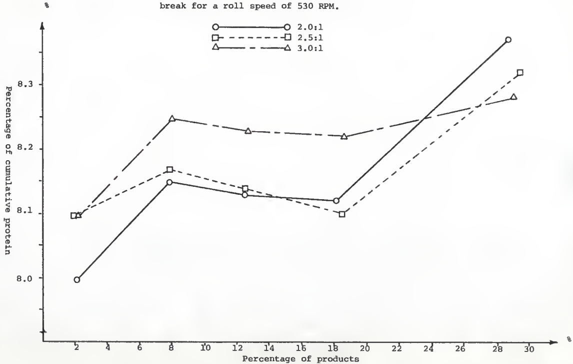


Figure 13. Cumulative protein curves of the first break for a roll speed of 670 RPM.

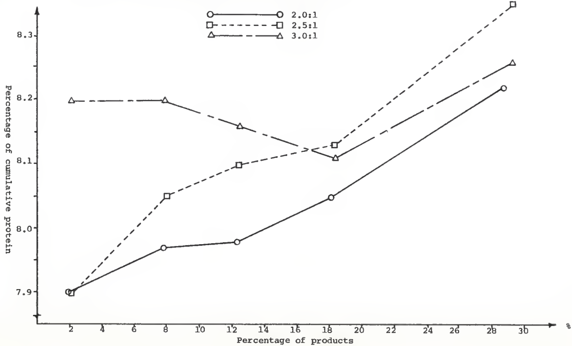


Figure 14. Cumulative protein curves of the second break for a first break roll speed of 370 RPM.

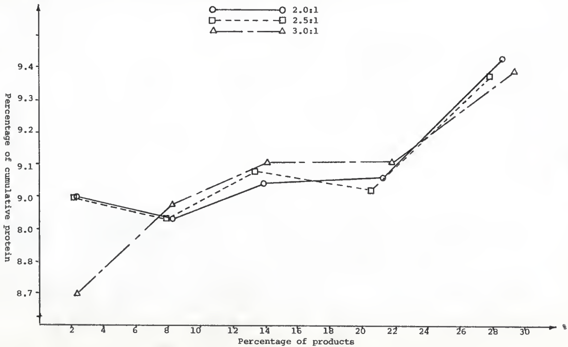


Figure 15. Cumulative protein curves of the second break for a first break roll speed of 530 RPM.

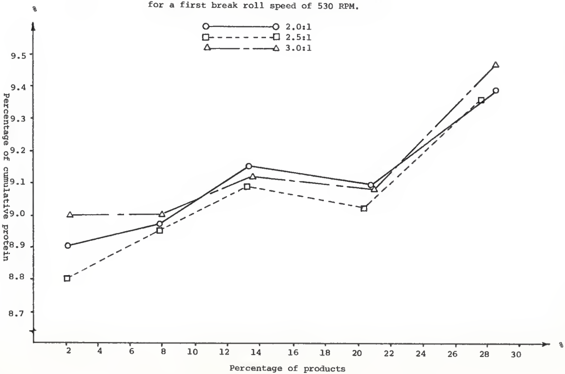


Figure 16. Cumulative protein curves of the second break for a first break roll speed of 670 RPM.

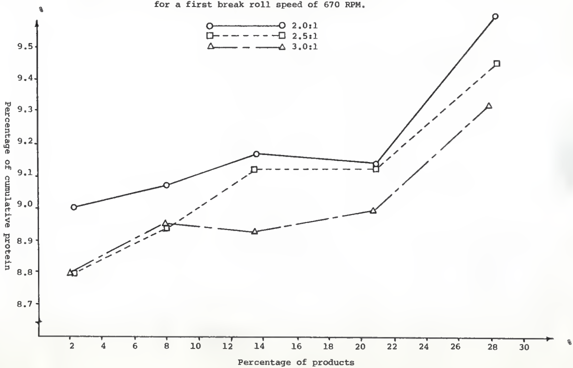


Figure 17. Cumulative protein curves of the combined first and second break for a first break roll speed of 370 RPM.

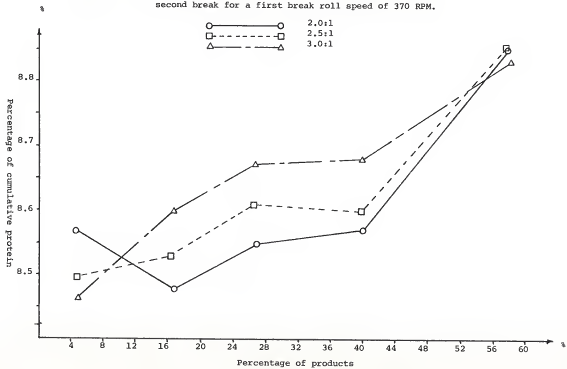


Figure 18. Cumulative protein curves of the combined first and second break for a first break roll speed of 530 RPM.

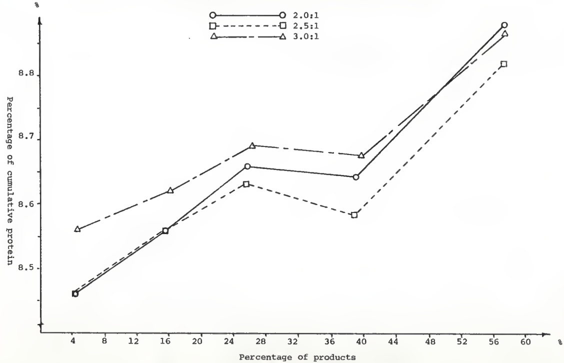
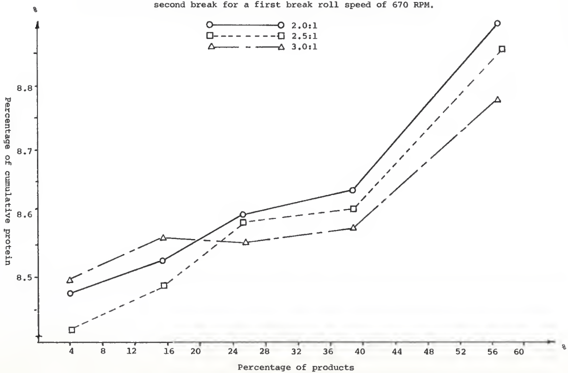


Figure 19. Cumulative protein curves of the combined first and second break for a first break roll speed of 670 RPM.



differential of 3.0:1 was higher in the cumulative protein in the initial part of curves than the other differentials.

No noticeable difference was found in Figures 14 to 19 for the second and combined first and second break fractions.

II. Comparison of Ash/Protein Contents.

Data were analyzed using the analysis of variance technique. The least significant difference (LSD) method was used for multiple comparisons among means.

The following model was assumed:

$$X_{ijk} = u + S_i + D_j + (S*D)_{ij} + e_{ijk}$$

where

X_{ijk} : Ash/protein content.

u : Overall mean of ash/protein content.

S_i : Roll speed effect.

D_j : Differential effect.

$(S*D)_{ij}$: Roll speed and differential interaction.

e_{ijk} : Experimental error.

$i = 1,2,3.$

$j = 1,2,3.$

$k = 1,2.$

In this design, 3 levels of the roll speed factor and 3 levels of the differential factor were considered. With 3 levels, the main effects of roll speed in the analysis of variance had (3-1) d.f.(Degree of Freedom) and those of differential also had (3-1) d.f. Since there were 3x3 treatment combinations, the treatment Sum of Square (S.S.) had (3x3-1) d.f. Consequently, there remained (3-1)(3-1) d.f. which represented the roll speed and differential interaction. The total d.f. was (18-1), since 2 replications were involved. Consequently, the experimental error had ((18-1)-(3-1)-(3-1)-(3-1)(3-1)) d.f. S.S. for each source of variance on the tables was calculated according to the following equations:

S.S. for roll speed = II - V

S.S. for differential = III - V

S.S. for roll speed and differential interaction

= IV + V - II - III

S.S. for experimental error

= I - IV

where

$$I = \sum_{i=1}^{3} \sum_{j=1}^{3} \sum_{k=1}^{2} X_{ijk}^{2}$$

$$II = \sum_{i=1}^{3} X_{i..}^{2}/6$$

• indicates the sum over the i^{th} treatment, j^{th} treatment, or k^{th} replication.

$$III = \sum_{j=1}^{3} X_{.j.}^{2}/6$$

$$IV = \sum_{i=1}^{3} \sum_{j=1}^{3} X_{ij.}^{2}/2$$

$$V = X_{...}^{2}/18$$

The Mean Square (M.S.) for each source of variance was calculated by dividing S.S. by d.f. Each F-ratio was calculated by dividing each M.S. by its error M.S. and compared to the F-value in the F-table for the 0.01 significance level. An F-ratio larger than the F-value from the F-table would mean that the factor being tested has a significant effect on ash/protein contents. In that case, the least significant difference (LSD) method was employed to compare the ash/protein content means. The LSD was calculated by the following equation:

$$LSD = (\text{error M.S.})^{1/2} \times t_{0.01,v}(2/n)^{1/2}$$

where

n = the number of observations per mean.

v = d.f. for experimental error.

t = t-value from the t-table given with v d.f.

The results of these statistical analyses were summarized in Tables 11 to 13.

A. Effect of first break differentials.

The following results were obtained from Tables 11 to 13:

1. Ash contents.

a. First break -20LW+30LW. (Figure 20)

Ash content for a differential of 2.5:1 was significantly lower and that for a differential of 2.0:1 was significantly higher than those for the other differentials.

b. First break -30LW+40LW. (Figure 21)

Ash content for a differential of 2.5:1 was slightly lower than those for the other differentials, although the differences were not statistically significant.

c. First break -40LW+60SS. (Figure 22)

Ash content for a differential of 3.0:1 was significantly higher than those for the other differentials. Moreover, ash content for a differential of 2.5:1 was slightly higher than that for a differential of 2.0:1, although the difference was not statistically significant.

d. First break -60SS+10XX. (Figure 22)

There was a clear indication that ash content increased with an increase in differential.

e. First break -10XX(Flour). (Figure 22)

Ash content for a differential of 3.0:1 waa significantly higher than thoae for the other differentials. Moreover, ash content for a differential of 2.5:1 was slightly higher than that for a differential of 2.0:1, although the difference waa not statiatically significant.

f. Second break -20LW+30LW. (Figure 20)

Ash content for a first break differential of 2.5:1 waa significantly lower than those for the other differentiala.

g. Second break -30LW+40LW (Figure 21)

Ash content for a first break differential of 2.0:1 was significantly higher than those for the other differentials. Moreover, a first break differential of 2.5:1 was lower in ash content than that of 3.0:1, although the difference was not statistically significant.

2. Protein contents.

a. First break -20LW+30LW. (Figure 23)

Protein content for a differential of 3.0:1 waa significantly lower than those for the other differentiala.

b. Firat break -40LW+60SS. (Figure 24)

The higher the differential, the higher the protein content, although the differences were not statistically aignificant.

c. Firat break -60SS+10XX. (Figure 24)

The higher the differential, the higher the protein content, although the differencea were not atatistically significant.

According to the above results, the first break differential had significant effects on the ash contents of the firat break fractions. It

Table 11

Results of the analysis of variance tables.

	Ash		Protein	
	Speed	Differential	Speed	Differential
First break				
-20LW +30LW	*	*	-	*
-30LW +40LW	-	-	-	-
-40LW +60SS	-	*	-	-
-60SS+10XX	-	*	-	-
-10XX	*	*	-	-
Second break				
-20LW +30LW	*	*	-	-
-30LW +40LW	*	*	-	-
-40LW +60SS	-	-	-	-
-60SS +10XX	-	-	-	-
-10XX	-	-	-	-

* Significant at the 0.01 level.

\- Not significant at the 0.01 level.

Table 12

Least significant difference for the ash content means of each fraction.

Fraction	LSD	Roll speed (RPM) 370	530	670	Differential 2.0:1	2.5:1	3.0:1
First break							
-20LW +30LW	0.0420	0.8650^{a}	0.9080^{b}	0.8580^{a}	0.9230^{C}	0.8320^{A}	0.8770^{B}
-30LW +40LW	0.0188	0.5280^{a}	0.5270^{a}	0.5220^{a}	0.5220^{A}	0.5180^{A}	0.5370^{A}
-40LW +60SS	0.0166	0.4420^{a}	0.4570^{a}	0.4380^{a}	0.4370^{A}	0.4400^{A}	0.4600^{B}
-60SS +10XX	0.0088	0.3920^{a}	0.3980^{a}	0.4000^{a}	0.3720^{A}	0.3930^{B}	0.4250^{C}
-10XX(Flour)	0.0108	0.3770^{a}	0.4000^{b}	0.4030^{b}	0.3780^{A}	0.3870^{A}	0.4150^{B}
Second break							
-20LW +30LW	0.0133	1.3870^{b}	1.4300^{c}	1.3600^{a}	1.4270^{B}	1.3230^{A}	1.4270^{B}
-30LW +40LW	0.0313	0.3970^{a}	0.4100^{a}	0.4570^{b}	0.4580^{B}	0.3920^{A}	0.4130^{A}
-40LW +60SS	0.0177	0.3450^{a}	0.3480^{a}	0.3580^{a}	0.3480^{A}	0.3520^{A}	0.3520^{A}
-60SS +10XX	0.0166	0.3230^{a}	0.3400^{a}	0.3280^{a}	0.3320^{A}	0.3320^{A}	0.3280^{A}
-10XX(Flour)	0.0188	0.3520^{a}	0.3700^{a}	0.3720^{a}	0.3600^{A}	0.3580^{A}	0.3750^{A}

a,b,&c ----- Values with the same letter are not significantly different at the 0.01 level.
A,B,&C ----- Values with the same letter are not significantly different at the 0.01 level.

Table 13

Least significant difference for the protein content means of each fraction.

Fraction	LSD	Roll speed (RPM)			Differential		
		370	530	670	2.0:1	2.5:1	3.0:1
First break							
-20LW +30LW	0.2167	8.5670^{a}	8.6170^{a}	8.5500^{a}	8.6170^{B}	8.7000^{B}	8.4170^{A}
-30LW +40LW	0.2027	8.1330^{a}	8.1000^{a}	8.1170^{a}	8.0830^{A}	8.1330^{A}	8.1330^{A}
-40LW +60SS	0.1327	8.0330^{a}	8.1000^{a}	8.0830^{a}	8.0330^{A}	8.0830^{A}	8.1000^{A}
-60SS +10XX	0.1876	8.0830^{a}	8.2170^{a}	8.0670^{a}	8.0500^{A}	8.1330^{A}	8.1830^{A}
-10XX(Flour)	0.1532	8.0670^{a}	8.0330^{a}	8.0000^{a}	8.0000^{A}	7.9670^{A}	8.1330^{A}
Second break							
-20LW +30LW	0.2900	10.3330^{a}	10.3330^{a}	10.4830^{a}	10.4830^{A}	10.3330^{A}	10.3330^{A}
-30LW +40LW	0.2074	9.0170^{a}	8.9500^{a}	9.1000^{a}	9.0500^{A}	8.9670^{A}	9.0500^{A}
-40LW +60SS	0.1769	9.2500^{a}	9.3000^{a}	9.1170^{a}	9.2830^{A}	9.2170^{A}	9.1670^{A}
-60SS +10XX	0.1251	8.9330^{a}	9.0000^{a}	9.0000^{a}	8.9670^{A}	8.9670^{A}	9.0000^{A}
-10XX(Flour)	0.1170	8.8670^{a}	8.9000^{a}	8.8500^{a}	8.9500^{A}	8.8500^{A}	8.8170^{A}

a,b,&c ----- Values with the same letter are not significantly different at the 0.01 level.

A,B,&C ----- Values with the same letter are not significantly different at the 0.01 level.

also hsd significant effects on the ash contents of the coarser fractions of the second bresk, even when the second break differentisl was held constant. The protein contents of milled products were much less susceptible to chsnges in differentials.

For convenience' sake, the products through the 20LW sieve and over the 40LW sieve were classified as the coarse middling fraction, and the products through the 40LW sieve and over the 10XX sieve were classified ss the fine middling fraction.

A first break differential of 2.5:1 produced the coarse middlings with the lowest ash content through the first and second break grindings. The reason for this may be that s first break differential of 2.5:1 provided the optimum shearing for separating large chunks of the endosperm from the bran and performed its task in the best manner for the second break operation separating large chunks of the endosperm from the first break tailover. A first bresk differential of 3.0:1 scratched the bran into finer fragments due to too much shearing, and that of 2.0:1 did not relesse the endosperm from the brsn efficiently due to too little shearing.

In finer fractions, including flour of the first break, the higher the differential, the higher the ash content. This trend is also explained by the increased scratching action due to higher differentials which pulverizes the bran and releases more endosperm cells from the peripheral area where the cells are high in ssh.

Higher differentials also increased the protein contents of the fine middling fractions of the first break. This is explained by the same reason for ash, since ssh and protein are distributed in a wheat kernel with the same grsdient.(12)

Results of the statistical analysis agree with observed trends in the cumulative ash and protein curves.

B. Effects of first break roll speeds.

The following results were obtained from Tables 11 to 13:

1. Ash contents.

a. First break -20LW+30LW. (Figure 25)

Ash content for a roll speed of 530 RPM was significantly higher than those for the other roll speeds. Moreover, ash content for a roll speed of 670 RPM was slightly lower than that for a roll speed of 370 RPM, although the difference was not statistically significant.

b. First break -10XX(Flour). (Figure 26)

Ash content for a roll speed of 370 RPM was significantly lower than those for the other roll speeds. Moreover, ash content for a roll speed of 670 RPM was slightly higher than that for a roll speed of 530 RPM.

c. Second break -20LW+30LW. (Figure 25)

Ash content for a first break roll speed of 530 RPM was significantly higher and that for a first break roll speed of 670 RPM was significantly lower than those for the other roll speeds.

d. Second break -30LW+40LW. (Figure 27)

Ash content for a first break roll speed of 670 RPM was significantly higher than those for the other roll speeds.

2. Protein contents.

No significant difference was found.

According to the above results, the protein contents of milled products were not affected by the first break roll speed. However, the first break roll speed had significant effects on the ash contents of some first and second break fractions.

The differences in the ash contents of flour fractions in the first bresk sre explained by the increased scalping action due to higher speeds. On the other hand, the effect of roll speed on the ash contents of the first and second break coarse middlings was not conclusive for finding which roll speed gives the best results.

Since a first break differential of 2.5:1 gave the optimum shearing, the ash contents of the coarse middlings was compared within this differential. (Figure 28 and Tsble 14) This comparison shows that the combination of s differential of 2.5:1 and a roll speed of 670 RPM resulted in a minimum ash content in a fraction through the 20LW sieve and over the 30LW sieve of the first break. The variations of the ash contents of the other fractions were within 0.01%. On the other hand, the extraction rste of a frsction, through the 20LW sieve and over the 30LW sieve, of the first break was higher thsn those of the other coarse middling fractions. Therefore, this frsction had the most predominant influence on the ash content of the total coarse middlings extracted in this experiment.

From the discussions above, it can be concluded thst a first bresk roll speed of 670 RPM produced the coarse middlings with the lowest ash content when the first break roll were driven at a differential of 2.5:1.

III. Equations to predict ash and protein contents.

Regression lines for fractions with significant differences in ash or protein contents in the analysis of vsriance tables were calculated through a statistical computer analysis to predict ash and protein contents from roll speed snd/or differential used under the conditions of this experiment.

These equations are shown in Table 15.

In this experiment, regression lines for ash contents of the first break fractions have higher R^2 coefficients than do the other regression lines. In other words, regression lines for ash contents of the first break fractions showed a better fit to the data than the others.

For a better analysis, future experiments should have more replications and levels of roll speed and differential.

Figure 20

Effect of differential on the ash content.
(First and second breaks,-20LW+30LW)

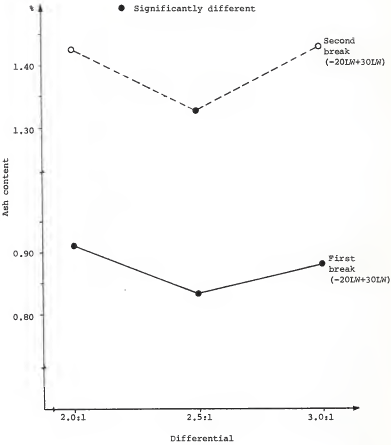


Figure 21

Effect of differential on the ash content.
(First and second breaks, -30LW+40LW)

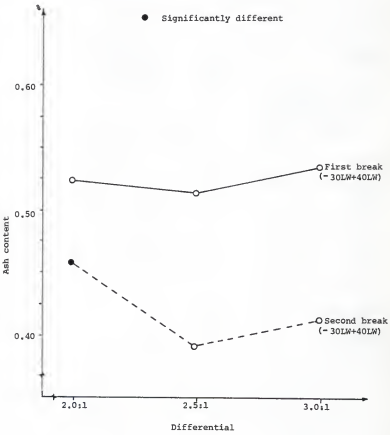


Figure 22

Effect of differential on the ash content
(First break, -40LW+60SS, -60SS+10XX, -10XX)

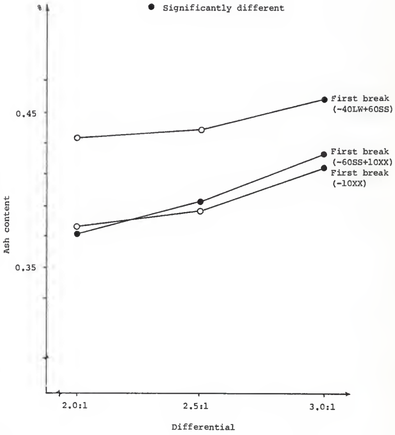


Figure 23

Effect of differential on the protein content.
(First break, -20LW+30LW)

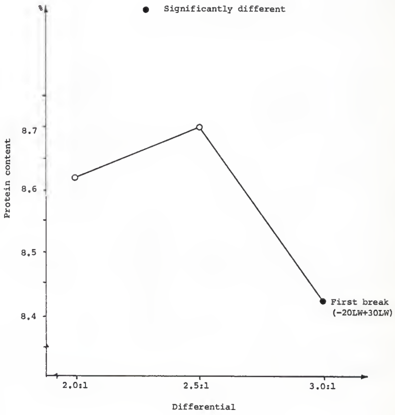


Figure 24

Effect of differential on the protein content.
(First break, -40LW+60SS, -60SS+10XX)

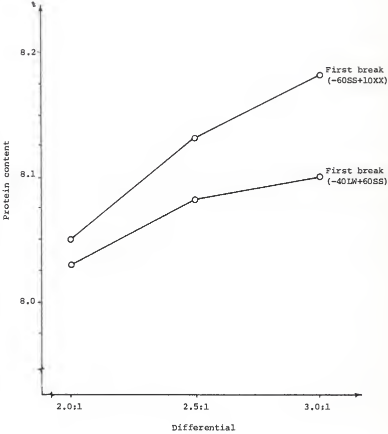


Figure 25

Effect of roll speed on the ash content.
(First and second breaks, -20LW+30LW)

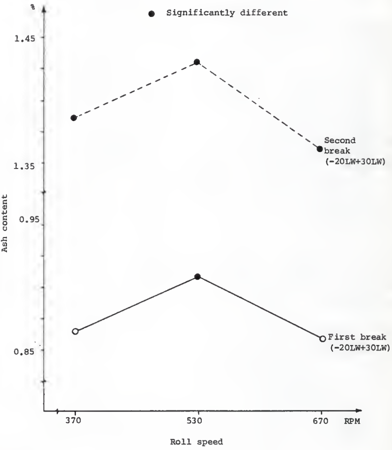


Figure 26

Effect of roll speed on the ash content.
(First break, -10XX)

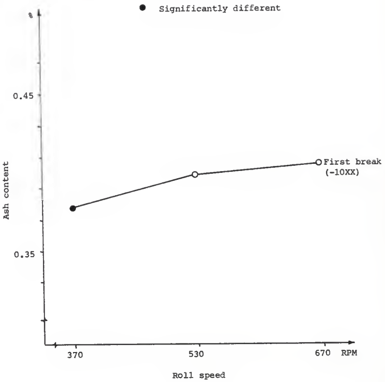


Figure 27

Effect of roll speed on the ash content.
(Second break, -30LW+40LW)

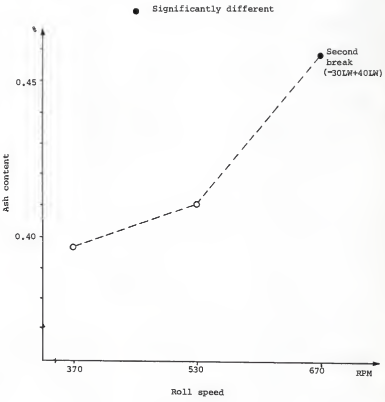


Figure 28

Comparison of ash contents of fractions through the 20LW sieve and over the 30LW sieve of the first break.

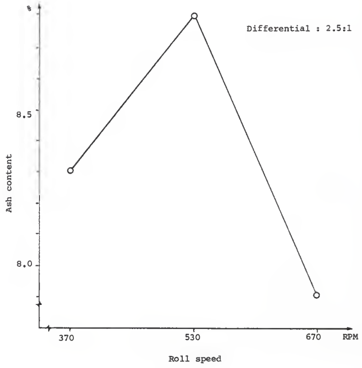


Table 14.

Ash contents of the coarser middling fractions ground with a first break differential of 2.5:1.

	Roll speed(RPM)		
	370	530	670
First break			
-20LW+30LW	0.83	0.88	0.79
-30LW+40LW	0.52	0.52	0.53
Second break			
-20LW+30LW	1.32	1.33	1.32
-30LW+40LW	0.39	0.39	0.40

Table 15.

Equations to predict ash and protein contents.

		Fraction	Equation	R^2
Ash content (Y)				
	First break	-20LW +30LW	$Y=2.656667-1.413333xD+0.273333xD^2$	0.6154873
		-40LW +60SS	$Y=0.415000+0.004162xD^2$	0.4020194
		-60SS +10XX	$Y=0.328023+0.010698xD^2$	0.9360465
		-10XX(Flour)	$Y=0.331824+0.000047xSxD$	0.7244936
	Second break	-20LW +30LW	$Y=1.416853-0.00000009xS^2$	0.0320024
		-30LW +40LW	$Y=0.364873+0.00000019xS^2$	0.2904311
Protein content (Y)				
	First break	-20LW +30LW	$Y=8.849225-0.042303xD^2$	0.2742066

Y : Ash or protein content predicted.

D : Differential.

S : Roll speed.

Summary and Conclusions

Under the conditiona used in this experiment, the following conclusions were obtained:

1. The first break differential had significant effecta on the ash contents of the first break products. It also had significant effects on the ash contents of the second break products, even when the second break differential was held constant.

2. The first break differential had more significant effects on the ash contents of the first and second break products than did the first break roll speed.

3. The ash contents of milled products were much more susceptible to changes in differentials than were the protein contents. The first break roll speed had no effects on the protein contents.

4. A first break differential of 2.5:1 gave the most satisfactory results, because it produced the coarse middlings with the lowest aah content through the first and second break grindings. The reason for thia is that, in the first break, a first break differential of 2.5:1 provided the optimum shearing force for separating large chunka of the endosperm from the bran and performed its task in the beat manner for the tailover being fed to the second break.

5. There was a positive correlation between differentials and ash contents of the finer fractions of the first break. As the differential increased, the ash contents of the finer fractions of the first break increased. The reason for this is that the increased scratching action due to higher differentials pulverized the bran and released more endosperm cells from the peripheral area where the cells were high in ash.

6. Under the conclusion that a first break differential of 2.5:1 wss best, s first break roll speed of 670 RPM gave the most satisfactory results. This is so, since the first break driven at 670 RPM with s differential of 2.5:1 produced the coarse middlings with the lowest ssh content. In other words, this combination sepsrated large chunks of the pure endosperm from the bran most efficiently.

Suggestions for Future Work

The extension of this research may be directed to experiments including the following:

1. Use of full scsle roller mill equipment including a fixed reduction system.

2. Design of conditions using variable second and third break setting and all possible combinations of those settings.

3. Search for the optimum conditions of the head reduction and/or sizing systems, changing differentisls, roll diameters, and roll speeds, to produce a flour with the lowest possible ash content at the highest possible extraction.

4. Using this same experiment on wheats having different characteristics, such as hardness and moisture content.

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Appendix A

Cumulative Ash Calculations

Table A-1.

Cumulative ash calculations of the first break for a roll speed of 370 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX −	0.37	2.2	0.814	0.814	2.2	0.370
	10XX +	0.37	6.1	2.257	3.071	8.3	0.370
	60SS +	0.44	4.6	2.024	5.095	12.9	0.395
	40LW +	0.51	5.8	2.958	8.053	18.7	0.431
	30LW +	0.91	10.7	9.737	17.790	29.4	0.605
2.5:1	10XX −	0.37	2.2	0.814	0.814	2.2	0.370
	10XX +	0.39	6.1	2.379	3.193	8.3	0.385
	60SS +	0.44	4.8	2.112	5.305	13.1	0.405
	40LW +	0.52	6.0	3.120	8.425	19.1	0.441
	30LW +	0.83	11.1	9.213	17.638	30.2	0.584
3.0:1	10XX −	0.40	2.1	0.840	0.840	2.1	0.400
	10XX +	0.42	5.9	2.478	3.318	8.0	0.415
	60SS +	0.46	4.6	2.116	5.434	12.6	0.431
	40LW +	0.56	5.7	3.192	8.626	18.3	0.471
	30LW +	0.86	10.8	9.288	17.914	29.1	0.616

Table A-2.

Cumulative ash calculations of the first break for a roll speed of 530 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX −	0.38	2.1	0.798	0.798	2.1	0.380
	10XX +	0.38	5.8	2.204	3.002	7.9	0.380
	60SS +	0.45	4.6	2.070	5.072	12.5	0.406
	40LW +	0.54	5.7	3.078	8.150	18.2	0.448
	30LW +	0.95	10.7	10.165	18.315	28.9	0.634
2.5:1	10XX −	0.40	2.1	0.840	0.840	2.1	0.400
	10XX +	0.39	5.9	2.301	3.141	8.0	0.393
	60SS +	0.45	4.7	2.115	5.256	12.7	0.414
	40LW +	0.52	5.9	3.068	8.324	18.6	0.448
	30LW +	0.88	10.7	9.416	17.740	29.3	0.605
3.0:1	10XX −	0.43	2.2	0.946	0.946	2.2	0.430
	10XX +	0.43	5.9	2.537	3.483	8.1	0.430
	60SS +	0.48	4.7	2.256	5.739	12.8	0.448
	40LW +	0.53	5.9	3.127	8.866	18.7	0.474
	30LW +	0.90	10.6	9.540	18.406	29.3	0.628

Table A-3.

Cumulative ash calculations of the first break for a roll speed of 670 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX −	0.39	2.0	0.780	0.780	2.0	0.390
	10XX +	0.38	5.8	2.204	2.984	7.8	0.383
	60SS +	0.43	4.6	1.978	4.962	12.4	0.400
	40LW +	0.52	5.8	3.016	7.978	18.2	0.438
	30LW +	0.92	10.6	9.752	17.730	28.8	0.616
2.5:1	10XX −	0.40	2.0	0.800	0.800	2.0	0.400
	10XX +	0.40	5.9	2.360	3.160	7.9	0.400
	60SS +	0.44	4.7	2.068	5.228	12.6	0.415
	40LW +	0.53	6.0	3.180	8.408	18.6	0.452
	30LW +	0.79	11.0	8.690	17.098	29.6	0.578
3.0:1	10XX −	0.43	2.1	0.903	0.903	2.1	0.430
	10XX +	0.43	5.9	2.537	3.440	8.0	0.430
	60SS +	0.45	4.5	2.025	5.465	12.5	0.437
	40LW +	0.53	5.9	3.127	8.592	18.4	0.467
	30LW +	0.87	10.9	9.483	18.075	29.3	0.617

Table A-4.

Cumulative ash calculations of the second break for a first break roll speed of 370 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential (1st break	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX −	0.35	2.4	0.840	0.840	2.4	0.350
	10XX +	0.32	5.9	1.888	2.728	8.3	0.329
	60SS +	0.34	5.6	1.904	4.632	13.9	0.333
	40LW +	0.41	7.3	2.993	7.625	21.2	0.360
	30LW +	1.42	7.4	10.508	18.133	28.6	0.634
2.5:1	10XX −	0.35	2.2	0.770	0.770	2.2	0.350
	10XX +	0.33	5.7	1.881	2.651	7.9	0.336
	60SS +	0.36	5.5	1.980	4.631	13.4	0.346
	40LW +	0.39	7.1	2.769	7.400	20.5	0.361
	30LW +	1.32	7.3	9.636	17.036	27.8	0.613
3.0:1	10XX −	0.37	2.4	0.888	0.888	2.4	0.370
	10XX +	0.32	5.9	1.888	2.776	8.3	0.334
	60SS +	0.34	5.8	1.972	4.748	14.1	0.337
	40LW +	0.40	7.6	3.040	7.788	21.7	0.359
	30LW +	1.42	7.6	10.792	18.580	29.3	0.634

Table A-5.

Cumulative ssh calculstions of the second bresk for a first break roll speed of 530 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differ-entisl (1st break	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX -	0.37	2.2	0.814	0.814	2.2	0.370
	10XX +	0.34	5.7	1.938	2.752	7.9	0.348
	60SS +	0.36	5.5	1.980	4.732	13.4	0.353
	40LW +	0.43	7.5	3.225	7.957	20.9	0.381
	30LW +	1.53	7.7	11.781	19.738	28.6	0.690
2.5:1	10XX -	0.37	2.3	0.851	0.851	2.3	0.370
	10XX +	0.34	5.7	1.938	2.789	8.0	0.349
	60SS +	0.35	5.5	1.925	4.714	13.5	0.349
	40LW +	0.39	7.4	2.886	7.600	20.9	0.364
	30LW +	1.33	7.4	9.842	17.442	28.3	0.616
3.0:1	10XX -	0.38	2.3	0.874	0.874	2.3	0.380
	10XX +	0.34	5.7	1.938	2.812	8.0	0.352
	60SS +	0.35	5.6	1.960	4.772	13.6	0.351
	40LW +	0.41	7.5	3.075	7.847	21.1	0.372
	30LW +	1.43	7.4	10.582	18.429	28.5	0.647

Table A-6.

Cumulative ash calculations of the second break for a first break roll speed of 670 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differ-ential (1st break	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX −	0.37	2.2	0.814	0.814	2.2	0.370
	10XX +	0.34	5.8	1.972	2.786	8.0	0.348
	60SS +	0.36	5.5	1.980	4.766	13.5	0.353
	40LW +	0.54	7.4	3.996	8.762	20.9	0.419
	30LW +	1.33	7.3	9.709	18.471	28.2	0.655
2.5:1	10XX −	0.36	2.1	0.756	0.756	2.1	0.360
	10XX +	0.33	5.8	1.914	2.670	7.9	0.338
	60SS +	0.35	5.4	1.890	4.560	13.3	0.343
	40LW +	0.40	7.2	2.880	7.440	20.5	0.363
	30LW +	1.32	7.2	9.504	16.994	27.7	0.612
3.0:1	10XX −	0.39	2.1	0.819	0.819	2.1	0.390
	10XX +	0.33	5.8	1.914	2.733	7.9	0.346
	60SS +	0.37	5.5	2.035	4.768	13.4	0.356
	40LW +	0.43	7.3	3.139	7.907	20.7	0.382
	30LW +	1.43	7.1	10.153	18.060	27.8	0.650

Table A-7.

Cumulative ash calculations of the combined first and second bresk for a first break roll speed of 370 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential (1st Break)	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX -	0.37	2.2	0.814	0.814		
		0.35	2.4	0.840	1.654	4.6	0.360
	10XX +	0.37	6.1	2.257	3.911		
		0.32	5.9	1.888	5.799	16.6	0.349
	60SS +	0.44	4.6	2.024	7.823		
		0.34	5.6	1.904	9.727	26.8	0.363
	40LW +	0.51	5.8	2.958	12.685		
		0.41	7.3	2.993	15.678	39.9	0.393
	30LW +	0.91	10.7	9.737	25.415		
		1.42	7.4	10.508	35.923	58.0	0.619
2.5:1	10XX -	0.37	2.2	0.814	0.814		
		0.35	2.2	0.770	1.584	4.4	0.360
	10XX +	0.39	6.1	2.418	4.002		
		0.33	5.7	1.881	5.883	16.2	0.363
	60SS +	0.44	4.8	2.112	7.995		
		0.36	5.5	1.980	9.975	26.5	0.376
	40LW +	0.52	6.0	3.120	13.095		
		0.39	7.1	2.769	15.864	39.6	0.401
	30LW +	0.83	11.1	9.213	25.077		
		1.32	7.3	9.636	34.713	58.0	0.599
3.0:1	10XX -	0.40	2.1	0.840	0.840		
		0.37	2.4	0.888	1.728	4.5	0.384
	10XX +	0.42	5.9	2.478	4.206		
		0.32	5.9	1.888	6.094	16.3	0.374
	60SS +	0.46	4.6	2.116	8.210		
		0.34	5.8	1.972	10.182	26.7	0.381
	40LW +	0.56	5.7	3.192	13.374		
		0.40	7.6	3.040	16.414	40.0	0.410
	30LW +	0.86	10.8	9.288	25.702		
		1.42	7.6	10.792	36.494	58.4	0.625

Tsble A-8.

Cumulative ash cslculstions of the combined first and second break for a first break roll speed of 530 RPM.

		A	Q	0 x A	S of 0xA	S of 0	S of QxA / S of Q
Differ-ential (1st Break)	Sieve mesh	% Ash (14% M.B.)	% of Whest	% of Wheat x % of Ash	Cumulative 0 x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX -	0.38	2.1	0.798	0.798		
		0.37	2.2	0.814	1.612	4.3	0.375
	10XX +	0.38	5.8	2.204	3.816		
		0.34	5.7	1.938	5.754	15.8	0.364
	60SS +	0.45	4.6	2.070	7.824		
		0.36	5.5	1.980	9.804	25.9	0.379
	40LW +	0.54	5.7	3.078	12.882		
		0.43	7.5	3.225	16.107	39.1	0.412
	30LW +	0.95	10.7	10.165	26.272		
		1.53	7.7	11.781	38.053	57.5	0.662
2.5:1	10XX -	0.40	2.1	0.840	0.840		
		0.37	2.3	0.851	1.691	4.4	0.384
	10XX +	0.39	5.9	2.301	3.992		
		0.34	5.7	1.938	5.930	16.0	0.371
	60SS +	0.45	4.7	2.115	8.045		
		0.35	5.5	1.925	9.970	26.2	0.381
	40LW +	0.52	5.9	3.068	13.038		
		0.39	7.4	2.886	15.924	39.5	0.403
	30LW +	0.88	10.7	9.416	25.340		
		1.33	7.4	9.842	35.182	57.6	0.611
3.0:1	10XX -	0.43	2.2	0.946	0.946		
		0.38	2.3	0.874	1.820	4.5	0.404
	10XX +	0.43	5.9	2.537	4.357		
		0.34	5.7	1.938	6.295	16.1	0.391
	60SS +	0.48	4.7	2.256	8.551		
		0.35	5.6	1.960	10.511	26.4	0.398
	40LW +	0.53	5.9	3.127	13.638		
		0.41	7.5	3.075	16.713	39.8	0.420
	30LW +	0.90	10.6	9.540	26.253		
		1.43	7.4	10.582	36.835	57.8	0.637

Table A-9.

Cumulative ash calculations of the combined first and second break for a first break roll speed of 670 RPM.

		A	Q	Q x A	S of QxA	S of Q	S of QxA / S of Q
Differential (1st Break)	Sieve mesh	% Ash (14% M.B.)	% of Wheat	% of Wheat x % of Ash	Cumulative Q x A	Cumulative % of Wheat	Cumulative % of Ash
2.0:1	10XX -	0.39	2.0	0.780	0.780		
		0.37	2.2	0.814	1.594	4.2	0.380
	10XX +	0.38	5.8	2.204	3.798		
		0.34	5.8	1.972	5.770	15.8	0.365
	60SS +	0.43	4.6	1.978	7.748		
		0.36	5.5	1.980	9.728	25.9	0.376
	40LW +	0.52	5.8	3.016	12.744		
		0.54	7.4	3.996	16.740	39.1	0.428
	30LW +	0.92	10.6	9.752	26.492		
		1.33	7.3	9.709	36.201	57.0	0.635
2.5:1	10XX -	0.40	2.0	0.800	0.800		
		0.36	2.1	0.756	1.556	4.1	0.380
	10XX +	0.40	5.9	2.360	3.916		
		0.33	5.8	1.914	5.830	15.8	0.369
	60SS +	0.44	4.7	2.068	7.898		
		0.35	5.4	1.890	9.788	25.9	0.378
	40LW +	0.53	6.0	3.180	12.968		
		0.40	7.2	2.880	14.848	39.1	0.405
	30LW +	0.79	11.0	8.690	24.538		
		1.32	7.2	9.504	34.042	57.3	0.594
3.0:1	10XX -	0.43	2.1	0.903	0.903		
		0.39	2.1	0.819	1.722	4.2	0.410
	10XX +	0.43	5.9	2.537	4.259		
		0.33	5.8	1.914	6.137	15.9	0.388
	60SS +	0.45	4.5	2.025	8.198		
		0.37	5.5	2.035	10.233	25.9	0.395
	40LW +	0.53	5.9	3.127	13.360		
		0.43	7.3	3.139	16.499	39.1	0.422
	30LW +	0.87	10.9	9.483	25.982		
		1.43	7.1	10.153	36.135	57.1	0.633

Appendix B

Cumulative Protein Calculations

Table B-1.

Cumulative protein calculations of the first break for a roll speed of 370 RPM.

Differential	Sieve mesh	P % Protein (14% M.B.)	Q % of Wheat	Q x P % of Wheat x % Protein	S of QxP Cumulative Q x P	S of Q Cumulative % of Wheat	S of QxP / S of Q Cumulative % of Protein
2.0:1	10XX -	8.1	2.2	17.82	17.82	2.2	8.10
	10XX +	8.0	6.1	48.80	66.62	8.3	8.03
	60SS +	8.0	4.6	36.80	103.42	12.9	8.02
	40LW +	8.0	5.8	46.40	149.82	18.7	8.01
	30LW +	8.7	10.7	93.09	242.91	29.4	8.26
2.5:1	10XX -	8.0	2.2	17.60	17.60	2.2	8.00
	10XX +	8.2	6.1	50.02	67.62	8.3	8.15
	60SS +	8.1	4.8	38.88	106.50	13.1	8.13
	40LW +	8.2	6.0	49.20	155.70	19.1	8.15
	30LW +	8.7	11.1	96.57	252.27	30.2	8.35
3.0:1	10XX -	8.2	2.1	17.22	17.22	2.1	8.20
	10XX +	8.2	5.9	48.38	65.60	8.0	8.20
	60SS +	8.1	4.6	37.26	102.86	12.6	8.16
	40LW +	8.2	5.7	46.74	149.60	18.3	8.17
	30LW +	8.4	10.8	90.72	240.32	29.1	8.26

Table B-2.

Cumulative protein calculations of the first break for a roll speed of 530 RPM.

Differential	Sieve mesh	P % Protein (14% M.B.)	Q % of Wheat	Q x P % of Wheat x % Protein	S of QxP Cumulative Q x P	S of Q Cumulative % of Wheat	S of QxP / S of Q Cumulative % of Protein
2.0:1	10XX -	8.0	2.1	16.80	16.80	2.1	8.00
	10XX +	8.2	5.8	47.56	64.36	7.9	8.15
	60SS +	8.1	4.6	37.26	101.62	12.5	8.13
	40LW +	8.1	5.7	46.17	147.79	18.2	8.12
	30LW +	8.8	10.7	94.16	241.95	28.9	8.37
2.5:1	10XX -	8.1	2.1	17.01	17.01	2.1	8.10
	10XX +	8.2	5.9	48.38	65.39	8.0	8.17
	60SS +	8.1	4.7	38.07	103.46	12.7	8.15
	40LW +	8.0	5.9	47.20	150.66	18.6	8.10
	30LW +	8.7	10.7	93.09	243.75	29.3	8.32
3.0:1	10XX -	8.1	2.2	17.82	17.82	2.2	8.10
	10XX +	8.3	5.9	48.97	64.58	8.1	8.25
	60SS +	8.2	5.9	38.54	105.33	12.8	8.23
	40LW +	8.2	5.9	48.38	153.71	18.7	8.22
	30LW +	8.4	10.6	89.04	242.75	29.3	8.28

Table B-3.

Cumulative protein calculations of the first break for a roll speed of 670 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differential	Sieve mesh	% Protein (14% M.B.)	% of Wheat	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX −	7.9	2.0	15.80	15.80	2.0	7.90
	10XX +	8.0	5.8	46.40	62.20	7.8	7.97
	60SS +	8.0	4.6	36.80	99.00	12.4	7.98
	40LW +	8.2	5.8	47.56	146.56	18.2	8.05
	30LW +	8.5	10.6	90.10	236.66	28.8	8.22
2.5:1	10XX −	7.9	2.0	15.80	15.80	2.0	7.90
	10XX +	8.1	5.9	47.79	63.59	7.9	8.05
	60SS +	8.2	4.7	38.54	102.13	12.6	8.11
	40LW +	8.2	6.0	49.20	151.33	18.6	8.14
	30LW +	8.7	11.0	95.70	247.03	29.6	8.36
3.0:1	10XX −	8.2	2.1	17.22	17.22	2.1	8.20
	10XX +	8.2	5.9	48.38	65.60	8.0	8.20
	60SS +	8.1	4.5	36.45	102.05	12.5	8.16
	40LW +	8.0	5.9	47.20	149.25	18.4	8.11
	30LW +	8.5	10.9	92.65	241.90	29.3	8.26

Table B-4.

Cumulative protein calculations of the second break for a first break roll speed of 370 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differential (1st Break)	Sieve mesh	% Protein (14% M.B.)	% of Wheat	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX -	9.0	2.4	21.60	21.60	2.4	9.00
	10XX +	8.9	5.9	52.51	74.11	8.3	8.93
	60SS +	9.2	5.6	51.52	125.63	13.9	9.04
	40LW +	9.1	7.3	66.43	192.06	21.2	9.06
	30LW +	10.5	7.4	77.70	269.76	28.6	9.43
2.5:1	10XX -	9.0	2.2	19.80	19.80	2.2	9.00
	10XX +	8.9	5.7	50.73	70.53	7.9	8.93
	60SS +	9.3	5.5	51.15	121.68	13.4	9.08
	40LW +	8.9	7.1	63.19	184.87	20.5	9.02
	30LW +	10.4	7.3	75.92	260.79	27.8	9.38
3.0:1	10XX -	8.7	2.4	20.88	20.88	2.4	8.70
	10XX +	9.1	5.9	53.69	74.57	8.3	8.98
	60SS +	9.3	5.8	53.94	128.51	14.1	9.11
	40LW +	9.1	7.6	69.16	197.67	21.7	9.11
	30LW +	10.2	7.6	77.52	275.19	29.3	9.39

Table B-5.

Cumulative protein calculations of the second break for a first break roll speed of 530 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differential (1st Break)	Sieve mesh	% Protein (14% M.B.)	% of Wheat	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX -	8.9	2.2	19.58	19.58	2.2	8.90
	10XX +	9.0	5.7	51.30	70.88	7.9	8.97
	60SS +	9.4	5.5	51.70	122.58	13.4	9.15
	40LW +	9.0	7.5	67.50	190.08	20.9	9.09
	30LW +	10.2	7.7	78.54	268.62	28.6	9.39
2.5:1	10XX -	8.8	2.3	20.24	20.24	2.3	8.80
	10XX +	9.0	5.7	51.30	71.54	8.0	8.94
	60SS +	9.3	5.5	51.15	122.69	13.5	9.09
	40LW +	8.9	7.4	65.86	188.55	20.9	9.02
	30LW +	10.3	7.4	76.22	264.77	28.3	9.36
3.0:1	10XX -	9.0	2.3	20.70	20.70	2.3	9.00
	10XX +	9.0	5.7	51.30	72.00	8.0	9.00
	60SS +	9.3	5.6	52.08	124.08	13.6	9.12
	40LW +	9.0	7.5	67.50	191.58	21.1	9.08
	30LW +	10.6	7.4	78.44	270.02	28.5	9.47

Table B-6.

Cumulative protein calculations of the second break for a first break roll apeed of 670 RPM.

Differential (1st break)	Sieve mesh	P % Protein (14% M.B.)	Q % of Wheat	Q x P % of Wheat x % Protein	S of QxP Cumulative Q x P	S of Q Cumulative % of Wheat	S of QxP / S of Q Cumulative % of Protein
2.0:1	10XX -	9.0	2.2	19.80	19.80	2.2	9.00
	10XX +	9.1	5.8	52.78	72.58	8.0	9.07
	60SS +	9.3	5.5	51.15	123.73	13.5	9.17
	40LW +	9.1	7.4	67.34	191.07	20.9	9.14
	30LW +	10.9	7.3	79.57	270.64	28.2	9.60
2.5:1	10XX -	8.8	2.1	18.48	18.48	2.1	8.80
	10XX +	9.0	5.8	52.20	70.68	7.9	8.95
	60SS +	9.2	5.4	49.68	120.36	13.3	9.05
	40LW +	9.1	7.2	65.52	185.88	20.5	9.08
	30LW +	10.4	7.2	74.88	260.76	27.7	9.41
3.0:1	10XX -	8.8	2.1	18.48	18.48	2.1	8.80
	10XX +	9.0	5.8	52.20	70.68	7.9	8.95
	60SS +	8.9	5.5	48.95	119.63	13.4	8.93
	40LW +	9.1	7.3	66.43	186.06	20.7	8.99
	30LW +	10.3	7.1	73.13	259.19	27.8	9.32

Table B-7.

Cumulative protein calculations of the combined first and second break for a first break roll speed of 370 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differential (1st Break)	Sieve mesh	% Protein (14% M.B.)	% of Wheat	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX −	8.1	2.2	17.82	17.82		
		9.0	2.4	21.60	39.42	4.6	8.57
	10XX +	8.0	6.1	48.80	88.22		
		8.9	5.9	52.51	140.73	16.6	8.48
	60SS +	8.0	4.6	36.80	177.53		
		9.2	5.6	51.52	229.05	26.8	8.55
	40LW +	8.0	5.8	46.40	275.45		
		9.1	7.3	66.43	341.88	39.9	8.57
	30LW +	8.7	10.7	93.09	434.97		
		10.5	7.4	77.70	512.67	58.0	8.84
2.5:1	10XX −	8.0	2.2	17.60	17.60		
		9.0	2.2	19.80	37.40	4.4	8.50
	10XX +	8.2	6.1	50.02	87.42		
		8.9	5.7	50.73	138.15	16.2	8.53
	60SS +	8.1	4.8	38.88	177.03		
		9.3	5.5	51.15	228.18	26.5	8.61
	40LW +	8.2	6.0	49.20	277.38		
		8.9	7.1	63.19	340.57	39.6	8.60
	30LW +	8.7	11.1	96.57	437.14		
		10.4	7.3	75.92	513.06	58.0	8.85
3.0:1	10XX −	8.2	2.1	17.22	17.22		
		8.7	2.4	20.88	38.10	4.5	8.47
	10XX +	8.2	5.9	48.38	86.48		
		9.1	5.9	53.69	140.17	16.3	8.60
	60SS +	8.1	4.6	37.26	177.43		
		9.3	5.8	53.94	231.37	26.7	8.67
	40LW +	8.2	5.7	46.74	278.11		
		9.1	7.6	69.16	347.27	40.0	8.68
	30LW +	8.4	10.8	90.72	437.99		
		10.2	7.6	77.52	515.51	58.4	8.83

Table B-8.

Cumulative protein calculations of the combined first and second break for a first break roll speed of 530 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differential (1st Break)	Sieve mesh	% Protein (14% M.B.)	% of Wheat	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX −	8.0	2.1	16.80	16.80		
		8.9	2.2	19.58	36.38	4.3	8.46
	10XX +	8.2	5.8	47.56	83.94		
		9.0	5.7	51.30	135.24	15.8	8.56
	60SS +	8.1	4.6	37.26	172.50		
		9.4	5.5	51.70	224.20	25.9	8.66
	40LW +	8.1	5.7	46.17	270.37		
		9.0	7.5	67.50	337.87	39.1	8.64
	30LW +	8.8	10.7	94.16	432.03		
		10.2	7.7	78.54	510.57	57.5	8.88
2.5:1	10XX −	8.1	2.1	17.01	17.01		
		8.8	2.3	20.24	37.25	4.4	8.47
	10XX +	8.2	5.9	48.38	85.63		
		9.0	5.7	51.30	136.93	16.0	8.56
	60SS +	8.1	4.7	38.07	175.00		
		9.3	5.5	51.15	226.15	26.2	8.63
	40LW +	8.0	5.9	47.20	273.35		
		8.9	7.4	65.86	339.21	39.5	8.59
	30LW +	8.7	10.7	93.09	432.30		
		10.3	7.4	76.22	508.52	57.6	8.83
3.0:1	10XX −	8.1	2.2	17.82	17.82		
		9.0	2.3	20.70	38.52	4.5	8.56
	10XX +	8.3	5.9	48.97	87.49		
		9.0	5.7	51.30	138.79	16.1	8.62
	60SS +	8.2	4.7	38.54	177.33		
		9.3	5.6	52.08	299.41	26.4	8.69
	40LW +	8.2	5.9	48.38	277.79		
		9.0	7.5	67.50	345.29	39.8	8.68
	30LW +	8.4	10.6	89.04	434.33		
		10.6	7.4	78.44	512.77	57.8	8.87

Table 8-9.

Cumulative protein calculationa of the combined first and second break for a first break roll apeed of 670 RPM.

		P	Q	Q x P	S of QxP	S of Q	S of QxP / S of Q
Differ- ential (lat Break)	Sieve mesh	% Protein (14% M.B.)	% of Whest	% of Wheat x % Protein	Cumulative Q x P	Cumulative % of Wheat	Cumulative % of Protein
2.0:1	10XX -	7.9	2.0	15.80	15.80		
		9.0	2.2	19.80	35.60	4.2	8.48
	10XX +	8.0	5.8	46.40	82.00		
		9.1	5.8	52.78	134.78	15.8	8.53
	60SS +	8.0	4.6	36.80	171.58		
		9.3	5.5	51.15	222.73	25.9	8.60
	40LW +	8.2	5.8	47.56	270.29		
		9.1	7.4	67.34	337.63	39.1	8.64
	30LW +	8.5	10.6	90.10	427.73		
		10.9	7.3	79.57	507.30	57.0	8.90
2.5:1	10XX -	7.9	2.0	15.80	15.80		
		8.8	2.1	18.48	34.28	4.1	8.36
	10XX +	8.1	5.9	47.79	82.07		
		9.0	5.8	52.20	134.27	15.8	8.50
	60SS +	8.2	4.7	38.54	172.81		
		9.2	5.4	49.68	222.49	25.9	8.59
	40LW +	8.2	6.0	49.20	271.69		
		9.1	7.2	65.52	337.21	39.1	8.62
	30LW +	8.7	11.0	95.70	432.91		
		10.4	7.2	74.88	507.79	57.3	8.86
3.0:1	10XX -	8.2	2.1	17.22	17.22		
		8.8	2.1	18.48	35.70	4.2	8.50
	10XX +	8.2	5.9	48.38	84.08		
		9.0	5.8	52.20	136.28	15.9	8.57
	60SS +	8.1	4.5	36.45	172.73		
		8.9	5.5	48.95	221.68	25.9	8.56
	40LW +	8.0	5.9	47.20	268.88		
		9.1	7.3	66.43	335.31	39.1	8.58
	30LW +	8.5	10.9	92.65	427.96		
		10.3	7.1	73.13	501.09	57.1	8.78

Appendix C

Duplicated Experimental Data

Table C-1.

Grinding with a differential of 2.0:1 and

a roll speed of 370 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	70.8	2.03	10.6	70.6	2.05	10.9
-20LW +30LW	10.7	0.91	8.7	10.6	0.90	8.6
-30LW +40LW	5.8	0.52	8.0	5.8	0.50	8.0
-40LW +60SS	4.5	0.44	8.1	4.6	0.43	7.9
-60SS +10XX	6.0	0.37	8.0	6.1	0.36	7.9
-10XX (Flour)	2.1	0.37	8.0	2.2	0.37	8.0
Second break						
+20 LW	42.4	3.06	12.3	41.9	3.09	12.6
-20LW +30LW	7.3	1.42	10.4	7.6	1.42	10.5
-30LW +40LW	7.2	0.41	9.0	7.3	0.40	9.2
-40LW +60SS	5.5	0.34	9.2	5.6	0.33	9.2
-60SS +10XX	5.9	0.32	8.8	5.9	0.32	8.9
-10XX (Flour)	2.4	0.34	9.0	2.3	0.35	9.0

* ——— 14% Moisture Basis

Table C-2.

Grinding with a differential of 2.5:1 and

a roll apeed of 370 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	70.0	2.07	10.6	69.7	2.05	10.9
-20LW +30LW	11.1	0.82	8.8	11.1	0.84	8.6
-30LW +40LW	6.0	0.52	8.3	6.0	0.51	8.1
-40LW +60SS	4.8	0.43	8.1	4.8	0.44	8.0
-60SS +10XX	6.1	0.39	8.1	6.1	0.39	8.2
-10XX (Flour)	2.1	0.37	8.0	2.2	0.36	7.9
Second break						
+20LW	42.7	3.04	12.2	41.8	3.05	12.5
-20LW +30LW	7.3	1.32	10.5	7.5	1.31	10.2
-30LW +40LW	7.1	0.39	9.0	7.2	0.38	8.8
-40LW +60SS	5.5	0.36	9.3	5.4	0.36	9.2
-60SS +10XX	5.7	0.32	8.9	5.6	0.34	8.9
-10XX (Flour)	2.3	0.35	9.0	2.2	0.34	8.9

* ——— 14% Moisture Basis

Table C-3.

Grinding with a differential of 3.0:1 and

a roll speed of 370 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	70.6	2.05	11.2	71.0	2.03	11.2
-20LW +30LW	10.8	0.86	8.4	10.8	0.86	8.3
-30LW +40LW	5.8	0.57	8.2	5.6	0.55	8.2
-40LW +60SS	4.5	0.46	8.1	4.6	0.45	8.0
-60SS +10XX	6.1	0.42	8.2	5.9	0.42	8.1
-10XX (Flour)	2.2	0.40	8.2	2.0	0.39	8.1
Second break						
+20 LW	41.3	3.06	12.4	41.6	3.05	12.1
-20LW +30LW	7.5	1.42	10.1	7.7	1.41	10.3
-30LW +40LW	7.5	0.42	9.0	7.7	0.38	9.1
-40LW +60SS	5.8	0.33	9.3	5.8	0.35	9.3
-60SS +10XX	6.0	0.32	9.1	5.9	0.32	9.0
-10XX (Flour)	2.5	0.37	8.6	2.3	0.36	8.7

* ——— 14% Moisture Basis

Table C-4.

Grinding with a differential of 2.0:1 and

a roll speed of 530 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	71.3	2.03	11.3	70.9	2.05	11.0
-20LW +30LW	10.6	0.93	8.7	10.8	0.97	8.8
-30LW +40LW	5.7	0.53	8.0	5.6	0.55	8.2
-40LW +60SS	4.6	0.44	8.1	4.6	0.45	8.1
-60SS +10XX	5.8	0.37	8.1	5.8	0.38	8.3
-10XX (Flour)	2.0	0.37	8.0	2.2	0.38	8.0
Second break						
+20LW	42.6	2.95	12.4	42.6	2.94	12.0
-20LW +30LW	7.7	1.52	10.0	7.6	1.53	10.3
-30LW +40LW	7.5	0.42	8.9	7.4	0.44	9.0
-40LW +60SS	5.5	0.35	9.2	5.5	0.36	9.5
-60SS +10XX	5.7	0.33	9.0	5.7	0.35	9.0
-10XX (Flour)	2.2	0.37	8.9	2.2	0.36	8.9

* ——— 14% Moisture Basis

Table C-5.

Grinding with a differential of 2.5:1 and

a roll apeed of 530 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
Firat break						
+20LW	70.7	2.05	10.9	70.6	2.03	11.1
-20LW +30LW	10.7	0.90	8.8	10.6	0.85	8.6
-30LW +40LW	5.9	0.51	7.9	5.9	0.52	8.1
-40LW +60SS	4.7	0.44	8.1	4.7	0.45	8.0
-60SS +10XX	5.8	0.39	8.3	6.0	0.38	8.1
-10XX (Flour)	2.1	0.40	8.1	2.1	0.40	8.0
Second break						
+20 LW	41.9	3.08	12.3	42.6	3.05	12.3
-20LW +30LW	7.6	1.34	10.3	7.2	1.32	10.3
-30LW +40LW	7.5	0.40	8.9	7.3	0.38	8.9
-40LW +60SS	5.7	0.34	9.3	5.5	0.35	9.2
-60SS +10XX	5.7	0.34	8.9	5.7	0.34	9.1
-10XX (Flour)	2.3	0.38	8.8	2.2	0.36	8.8

* ——— 14% Moisture Basis

Table C-6.

Grinding with a differential of 3.0:1 and

a roll speed of 530 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	70.7	2.04	11.6	70.9	2.05	11.1
-20LW +30LW	10.7	0.92	8.3	10.5	0.88	8.5
-30LW +40LW	5.9	0.52	8.1	5.9	0.53	8.3
-40LW +60SS	4.7	0.49	8.1	4.7	0.47	8.2
-60SS +10XX	5.9	0.43	8.2	5.9	0.43	8.3
-10XX (Flour)	2.2	0.43	8.0	2.1	0.42	8.1
Second break						
+20LW	42.1	3.07	12.1	42.4	3.08	12.6
-20LW +30LW	7.4	1.43	10.6	7.4	1.43	10.5
-30LW +40LW	7.5	0.40	9.0	7.5	0.42	9.0
-40LW +60SS	5.6	0.35	9.4	5.6	0.34	9.2
-60SS +10XX	5.8	0.33	9.0	5.7	0.35	9.0
-10XX (Flour)	2.3	0.37	9.1	2.3	0.38	8.9

* ——— 14% Moisture Basis

Table C-7.

Grinding with a differential of 2.0:1 and

a roll speed of 670 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	71.2	2.04	11.0	71.3	2.04	11.4
-20LW +30LW	10.6	0.90	8.5	10.5	0.93	8.4
-30LW +40LW	5.8	0.51	8.2	5.8	0.53	8.1
-40LW +60SS	4.6	0.44	8.0	4.6	0.42	8.0
-60SS +10XX	5.8	0.38	7.9	5.8	0.37	8.1
-10XX (Flour)	2.0	0.39	7.9	2.0	0.39	7.9
Second break						
+20LW	42.9	2.96	12.3	43.0	2.97	12.7
-20LW +30LW	7.5	1.33	10.7	7.2	1.32	11.0
-30LW +40LW	7.3	0.52	9.2	7.5	0.56	9.0
-40LW +60SS	5.3	0.36	9.3	5.6	0.35	9.3
-60SS +10XX	5.8	0.33	9.0	5.8	0.34	9.1
-10XX (Flour)	2.3	0.36	8.9	2.1	0.38	9.0

* ——— 14% Moisture Basis

Table C-8.

Grinding with a differential of 2.5:1 and

a roll speed of 670 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	70.5	2.07	11.4	70.4	2.05	11.5
-20LW +30LW	11.0	0.80	8.8	11.0	0.78	8.6
-30LW +40LW	5.9	0.53	8.3	6.0	0.52	8.1
-40LW +60SS	4.7	0.44	8.2	4.7	0.44	8.1
-60SS +10XX	5.9	0.40	8.0	5.9	0.40	8.1
-10XX (Flour)	2.0	0.40	7.9	2.0	0.39	7.9
Second break						
+20LW	43.1	3.05	12.3	42.7	3.08	12.5
-20LW +30LW	7.2	1.32	10.2	7.1	1.32	10.5
-30LW +40LW	7.1	0.39	9.0	7.2	0.41	9.2
-40LW +60SS	5.4	0.34	9.2	5.4	0.36	9.1
-60SS +10XX	5.7	0.33	9.0	5.8	0.32	9.0
-10XX (Flour)	2.0	0.37	8.8	2.1	0.35	8.8

* ——— 14% Moisture Basis

Table C-9.

Grinding with a differential of 3.0:1 and

a roll speed of 670 RPM.

	Extraction (%)	Ash* (%)	Protein* (%)	Extraction (%)	Ash* (%)	Protein* (%)
First break						
+20LW	71.0	2.06	11.2	70.4	2.06	11.5
-20LW +30LW	10.8	0.85	8.6	10.9	0.89	8.4
-30LW +40LW	5.9	0.53	8.0	5.8	0.52	8.0
-40LW +60SS	4.5	0.45	8.1	4.5	0.44	8.1
-60SS +10XX	5.9	0.43	8.2	6.1	0.42	8.1
-10XX (Flour)	2.0	0.43	8.3	2.2	0.42	8.1
Second break						
+20 LW	43.0	3.09	12.4	42.6	3.08	12.2
-20LW +30LW	7.1	1.43	10.2	7.2	1.42	10.3
-30LW +40LW	7.2	0.43	9.0	7.3	0.43	9.2
-40LW +60SS	5.6	0.36	8.9	5.4	0.38	8.9
-60SS +10XX	5.9	0.33	9.0	5.7	0.32	8.9
-10XX (Flour)	2.1	0.39	8.8	2.1	0.38	8.8

* ——— 14% Moisture Basis

List of Tables in Appendix

THE EFFECTS OF THE FIRST BREAK ROLLER MILL

DIFFERENTIALS AND SPEEDS

by

Noritaka Tsuge

B.S., Tokyo University, 1978

AN ABSTRACT OF A MASTER'S THESIS

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The object of this study is to find how the differentials and speeds on the first break influence the characteristics of the middlings extracted from the first and second break grindings and which differential or speed gives the best results for subsequent processes.

The variable factors on the first break in this experiment were:

(1) Roll speed.

(2) Roll differential.

Three levels of each factor were tested. Roll speeds tested were 370 RPM, 530 RPM, and 670 RPM. Differentials tested were 2.0:1, 2.5:1, and 3.0:1. Consequently, nine combinations of roll speeds and differentials were tested.

Other factors on the first break and all factors on the second break were held constant. Each grinding consisted of the first and second break rolls. All samples taken from each grinding were separated by size and analyzed for moisture, ash, and protein contents.

The test results indicated that:

(1) The first break differential had more significant effects on the ash contents of the first and second break fractions than did the first break roll speed.

(2) The ash contents of milled products were much more susceptible to changes in differentials than were the protein contents. The first break roll speed had no effect on the protein contents.

(3) A first break differential of 2.5:1 gave the most satisfactory results, because it produced the coarse middlings with the lowest ash content through the first and second break grindings. The reason for this is that, in the first break, a first break differential of 2.5:1 provided the optimum shearing force for separating large chunks of the endosperm from the bran and performed its task in the best manner for the tailover

being fed to the second break.

(4) There waa a positive correlation between differentials and ash contenta of the finer fractions of the first break. As the differential increased, the ash contents of the finer fractions of the first break increased. The reason for this is that the increased scratching action due to higher differentials which pulverizes the bran and releasea more endosperm cella from the peripheral area where the cells are high in ash.

(5) Under the conclusion that a first break differential of 2.5:1 was best, a first break roll speed of 670 RPM gave the most satisfactory results, because the first break driven at 670 RPM with a differential of 2.5:1 produced the coarse middlings with the lowest ash. In other words, thia combination aeparated large chunks of the pure endosperm from the bran most efficiently.