CONTROLLING FLOUR PROTEIN LEVEL BY USE OF AIR SEPARATION

by

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INTRODUCTION

Controlling of flour protein level has both commercial and laboratory value. When evaluating wheat flours, the protein level can influence the bread volume and final bread score. As the protein content increases usually the bread value increases. It is important to have a fair evaluation of a wheat flour independent of the protein content variation.

The purpose of this study was to develop a procedure by which flour protein level could be controlled by the use of air separation.

There are a number of factors which influence the protein level of wheat (15, 49, 60, 61, 62, 63). The environmental conditions when wheat is sown, the time of sowing, and the soil conditions have a direct bearing on protein level. The environmental conditions that follow sowing until harvest time also have a bearing on the protein level. The application of fertilizer, irrigation and the amount of rainfall influence the protein level of the wheat.

Once the wheat has been harvested and milled, there are still other methods which may be used to regulate the protein content of the flour. Flour streams in a flour mill vary considerably in protein content. First middlings flour may be 10 per cent protein while the fifth break flour may be as high as 15 or 17 per cent protein. The rest of the flour streams range between 10 and 17 per cent. A proper selection of the streams makes possible the control of flour protein

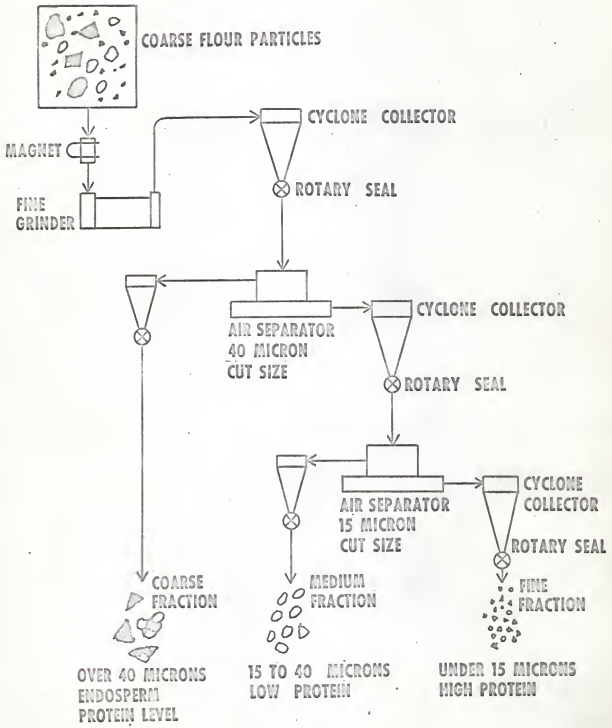
level. The method used to control flour protein level in this study was by air separation.

Flour, as made on a flour mill, consists of three basic types of components: (a) the very fine particles, which consist of a considerable amount of wedge protein, (b) the slightly larger starch particles, and (c) the chunks which are a combination of the protein and starch particles (76).

It was possible to concentrate the starch and protein into different fractions using the air separation method. A simple air classification procedure is shown in Fig. 1. The flour when reground before classification in a fine grinder facilitates the classification procedure. Fine grinding shakes loose some of the wedge protein sticking to larger starch granules, setting them free to be concentrated into different fractions. The flour when fed into the classifier makes a fine and coarse cut. The coarse cut consists of the chunks, which are approximately the same protein content as that of the parent flour. The fine cut when reclassified gives a high protein fraction, fine fraction, and a low protein coarse fraction. The reclassification procedure could be carried on as many times as desired.

In a classification procedure, three properties are basically utilized: differences in size, shape, and specific gravity. With a sieve, difference in size is the property used to make separations, though shape also plays a part. An air separator uses differences in size, shape, and specific gravity to make a separation. It is able to separate particles of a

FIG. I
SIMPLIFIED PROTEIN SHIFT PROCESS DIAGRAM



smaller size, where sieves fail. The fine fractions obtained by air separation are called sub-sieve size fractions.

The use of air separation makes it possible to obtain cake and bread flours from the same wheat mix on a commercial basis. The low protein or starchy fractions obtained make good cake flours. Air separation in the laboratory could be used to control protein content of flour for evaluation purposes (25). When evaluating wheat varieties for quality, there are a number of variables. For a good evaluation, a minimum number of variables is desirable. Protein level is a variable which has a marked effect on the evaluation procedures. In some evaluation work protein quantity is confused with quality. If it were possible to obtain all the flours from different wheats at the same protein level, a better evaluation of quality without regard to quantity would be possible. The importance of controlling protein level is recognized by many wheat research scientists.

REVIEW OF LITERATURE

The increase of wheat yields through fertilization is well known. Nitrogen fertilizers, properly used also raises protein content of wheat grain (14, 16, 17, 65).

In a study by Smith (65), nitrogen fertilizer in different quantities per acre was applied at different stages of wheat growth. The days of application varied from 55 days before flowering, to 40 days after flowering. Fifty pounds of this

fertilizer were applied at different times to the wheat lots. The protein content of the resultant wheat varied from 11-15 per cent. Finney and Barmore (18) reported that in baking there were large variations in loaf volume with different protein levels. "The major factor accounting for variation in loaf volume varied from 40-70 c.c. for a 1 per cent rise in protein content." In their report the authors stated "loaf volume--protein content regression lines for varieties, represent difference in protein quantity." They also tried to find a method to compensate for this variation in protein content.

A wheat variety-fertilizer interaction study was conducted by Schlehuber et al., (62). They concluded that, in regard to the protein content of grain, there was a greater difference (3.42%) between fertilizer treatment than between variety. "Under given climatic conditions variable soil fertility affects both yield and quality. By practicing a sound fertilization program the producer can upgrade the quality as well as the yield of wheat."

Fractionation studies by fine grinding and air classification of flours of the five varieties and seven fertilizer treatments as reported by Schlehuber (62) was made by Pfeifer et al., (57). They found that variations in protein shift, due to wheat variety, were greater than those due to fertilize levels.

Finney and Barmore (18) found great differentiations in loaf volume due to differences in protein content and pointed

out the importance of having uniform protein level for the purpose of evaluation of wheats. They arrived at formulas which compensated for variations in protein content of flours used in bread baking.

One formula was to divide loaf volume by flour protein content. Another formula subtracted X amount of volume (where X represents a fixed value) from the loaf volume and divide by the flour protein.

Attempts have been made to blend a low protein H.R.W. flour fraction (about 7 per cent protein) to spring wheat parent flour to bring them to a common protein level. This study was not continued long enough to reach conclusive results since the majority of the collaborators did not think it worthwhile.

Variations in flour particle size led workers to investigate different size ranges. Particle size classification greater than 60 microns is possible with wire cloth. W. S. Tyler Co. (69) claims wire cloth as efficient in this size range. Sieving is limited for measuring particle size and separating flours in the fine particle size range.

The interest of grinding flour into fine powder has led to other investigations of fine flours. The first problem was to measure particle size of fine flours. Fig. 2 shows the limits to particle size measuring equipment, some of which can be used in the particle size range of wheat flour.

In another study related to flour particle size Wichser's et al., (71, 72, 73, 74, 75) state "Flour particles have a

FIG. 2 LIMITS OF PARTICLE SIZE MEASURING EQUIPMENT

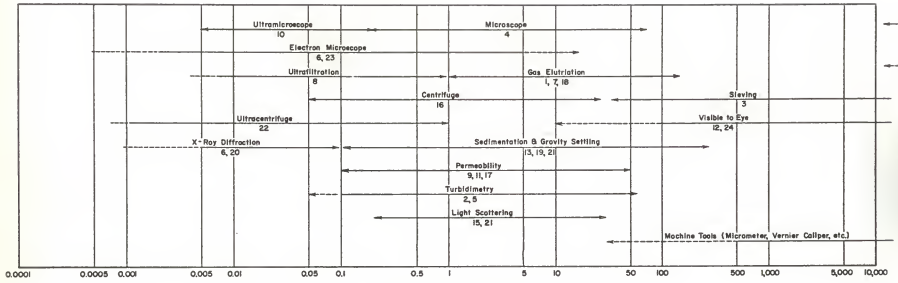


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Chart No. 1500-3

tendency to agglomerate, and the agglomerations are not broken up entirely during the sieving process." The accuracy of the particle size measurement by sieving is limited. Sieving does not remove extremely fine or pulverized bran chips, dirt, or foreign material. They found the Roller Particle Size Analyzer which uses air elutriation principle to be quite effective.

Handleman (32) listed some of the problems encountered when sieving was used to describe size distribution. Their objective of their work was to 1) determine precision of sieve analysis, and 2) detect common source of error in sieve analysis. Irani (37) (38) reviewed the different methods used for particle size distribution data. He described the size of a particle as "that dimension which best describes its degree of sub division." He further states: "Direct particle size measurements, whether microscopies or otherwise, are the only known standard methods."

The three major techniques for particle size distribution measurements are microscopy, sedimentation, and sieving. Usually methods based on other techniques either are limited in scope or give only an average size. The advantages of microscope techniques is their directness. Other methods measure a property of the particle, and then calculate the size.

Whitby (70) eliminated some of the major complications of the other sedimentation techniques by using a feeding suspension (layer), which has a lower density but a higher viscosity than the clean sedimentation liquid. The effect of density streaming

is minimized, and all particles start from the same level. He also used a streamlined sedimentation tube and a tapper to minimize the sticking of particles. The Whitby method gives the numerical value referred to as the Mass Median Diameter (MMD) which is the point where 50 per cent of the flour is finer than that size. It is possible to read directly from the plotted curve the amount, in per cent, finer than any particular particle size.

Another means of measuring particle size could be by permeation. The average size of a sample can be determined with a relative figure, sometimes quite accurate if the product has an uniform shape, by the passing of a liquid or air stream across a bed or column of material. This instrument made by the Fisher Scientific Company called the "Sub Sieve Sizer," is based on the Blaine principle (7). It employs the principle of permeability of the porous bed first used by Carman (8) on liquids, and later by Gooden and Smith (23) (24) in different fluids.

Shellenberger et al., (64), working with particles ranging from 38 to 150 microns, reported that smaller flour particles had higher ash content while protein increased as particle size decreased, except for the 0-38 micron fraction which was low in protein. The baking results obtained paralleled the protein content values. They also reported that the finest flour particles (less than 38 microns) produced good cakes and cookies while the coarse fraction flours produced poor cakes

and cookies. This series of flour granulation studies covered very extensively the fractions 38 microns and larger. Comparisons were made using different wheat flours. Baking, physical, dough properties, and analytical tests were made on the different size fractions. Below 38 microns was referred to as the Sub-Sieve Size range (35). Investigations in the Sub-Sieve Size range was not begun until the air classification procedure was introduced into the milling industry.

The air classifiers available could be classified as:

1. Whizzer type
2. Single Vortex
    a. Simple straight sides
    b. Complex sides with skimmers
    c. Distant sides
3. Centripetal
    a. Single deck
    b. Multi-deck

The type of air separator used in this study was a Centripetal Multi-deck type of unit manufactured by the Pillsbury Company. The small lab size unit requiring approximately 20-25 pounds sample is called the "Hurricane Turbo Separator."

Pfeifer and others (52, 53, 54, 55, 56, 57, 59, 66) have reported air classification work done on wheats and other cereal flours. Their conclusions state: "Hard wheats of less protein content can be fractionated to remove a low protein fraction and leave improved bread flours; soft wheats of high protein

content can be fractionated to the desired composition for use as cake and cookie flour; flour quality can be maintained and will be much less dependent on variety, location and growing conditions of the wheat." They found that ash was highest in the fine fractions and that it dropped progressively with protein content during classification. Both protein and ash increased in the coarse residue. Maltose values were highest in the fine fractions, which consisted of a large number of ruptured starch granules, dropping progressively during classification to values below those of the original flour. Commenting on the regrinding of flours, they wrote: "Regrinding the flour before classification increased the range of compositions of the fractions and also increased the yields of high and low protein fractions."

Griffin, (52) reporting on regrinding, states: "Regrinding increased ash of the fine fractions and usually lowered ash content of the coarse fractions. In most cases, ash content of the finest fractions was about double that of the parent flour. Maltose values increased somewhat during grinding partly because of particle size reduction. The maltose value in the finest fraction was from 1.5 to 2 times that of the parent flour fractionated." Results on repeated regrinding and air classification also produced a shifting to a higher protein value and a greater amount of the fine fractions. A corresponding decrease in the amount of flour took place in the coarser fractions (3, 11, 12, 13).

Gracza (29, 30, 31, 26, 27, 28) in studying Sub-Sieve Size fractions of soft wheat, reported that there are differences in their physical and chemical properties. Gracza also arrived at an equation defined as the degree of positive protein shifting, $+\delta$ which may be expressed mathematically as follows:

$$+\delta = \frac{1}{P} \sum_{x=1}^{x=n} (P_x - P)Y$$

where

δ = degree of protein shifting (per cent)

P = protein content of parent flour (per cent)

P_x = protein content of individual fractions having larger protein level than the parent (per cent)

P_z = protein content of individual fraction having lower protein level than the parent (per cent)

Y = yield of the individual fraction (per cent)

n = number of fractions produced out of the parent stock.

A positive shift in protein of the parent stock into certain fractions can be done only at the expense of a depletion of the same amount of protein from other fractions. This area is designated by the minus sign. This depletion is defined as the degree of negative protein shifting, $-\delta$ which may be expressed mathematically as:

$$-\delta = \frac{1}{P} \sum_{z=1}^{z=n} (P - P_z)Y$$

Therefore $+\delta = -\delta = \delta$ where δ is called the degree of protein shifting.

Gracza also defined critical cut "as an empirical efficiency measure composing particle size distribution of a coarse and fine fraction from an air-classification procedure." A neutral critical cut size designates that size at which a classification yields fine and coarse fractions with their protein content equal to that of the parent stock. Conclusions of Gracza's reports were that the Fisher average particle size indicates most likely some measure of specific surface. The petroleum ether in extractable lipid content of the fraction increases with protein content. Low pH values were associated with higher protein content. An increase of protein in a fraction decreased the specific gravity.

Nenninger (49) states five possible uses of air classified fractions:

> 1) Flour with low protein content for biscuit production, 2) Flour with low protein content which is especially granular as household flour, 3) Flour with less protein content for the starch industry, 4) Flour with high protein content for enrichment of baker's flour, and 5) Flour with exceptionally high protein content for the production of baked foods with low starch content.

Auer (3) also listed similar uses for the air classified flour fractions.

It has been found that the low protein fractions from air classified hard wheat makes excellent cake flours. They may even be considered as better cake flours than that obtained from soft wheat flours (34, 33, 2). Work done previously has

shown that protein and starch could be concentrated in different fractions by the use of air separation. The fractionation of flours made it possible to reconstitute the different fractions to vary the protein level.

In previous studies work was done on blending, by adding a starchy fraction from Hard Red Winter Wheat flour to Spring wheat flour to lower the protein level. This method was not used in favor of adding or removing fractions obtained by air classification from the same flour.

A number of methods for particle size distribution have been studied. The Whitby Sedimentation Particle Size distribution method was found to be very useful for an air classification study, as it gave an indication of the classifier performance.

To obtain the average particle diameter Fisher Sub-Sieve Size was found to be quick and accurate instrument.

MATERIALS AND METHODS

In this study two wheats of different protein content were milled on the Kansas State University Pilot Mill. The two straight grade flours of different protein levels were air classified into five Sub-Sieve Size (S.S.S.) fractions on the Hurricane air classifier.

The five fractions thus obtained from the parent flour (A) were separated and designated as follows:

1. Primary high protein fraction (B)

2. Secondary high protein fraction (C)
3. Small starch fraction (D)
4. Large starch fraction (E)
5. Chunks fraction (EE)

Fractions from the two wheat flours were blended to bring the protein to four levels, 9.9, 10.7, 11.5, and 13 per cent protein. In the protein blending procedure efforts were made to keep all properties of blends as close to the parent flour as possible.

Methods of Blending

After obtaining five fractions from a straight grade flour, a number of methods could be used for raising or lowering the protein content. These methods are:

Method A: Removing certain air separated fractions

Method B: Addition of certain air separated fractions from parent type flour to parent flour

Method C: Removing certain air separated fractions and adding other fractions in excess of the normal parent flour per cent.

Method D: Addition of air separated fractions from other than the parent flour to parent flour concerned.

Method E: Addition of certain mill streams

Method F: Addition of wet-processed starch or gluten.

In this study the majority of the protein blends were made using Methods A and B although for one blending procedure,

Method C was used.

Equipment

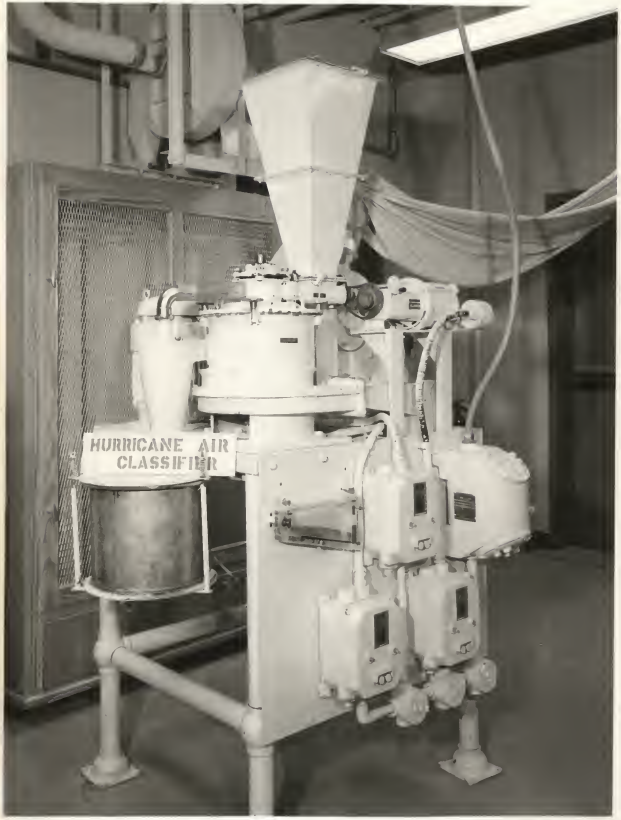
The Pillsbury Lab size Hurricane Air Classifier (Fig. 3) was used to make the flour fractions (20, 46, 47). The classifier itself consisted of a cylindrical classifier chamber 6 inches in diameter and 4 inches high. Air was pulled by means of a fan through the 3.5 inches diameter center opening. Air entered the classifier tangentially at the bottom through an inlet. The air followed a spiral or vortex path being defined by the size, shape and position of the vanes and decks placed around in the cylinderical zone of the classifier. Flour was fed by twin screws on top of the rotating decks. Then it was flung outward and accumulated a centrifugal force (Fig. 4).

There were two forces acting on any particle at all times in the classifier: the centrifugal force which tried to fling the particle outward, and the drag force, due to the air, acting in the opposite direction.

The two forces acting in opposite direction, (Fig. 5) governed the movement of the particle. A relatively coarse particle had a greater centrifugal force than the drag force. The coarse particle was thrown outward and was collected in a cyclone collector.

For the finer particles the drag force was greater than the centrifugal force. The fine material was pulled in with the air through the center opening to a cyclone where the material was

Fig. 3. Hurricane air classifier used for air separation of wheat flour in this study.


HURRICANE AIR
CLASSIFIER

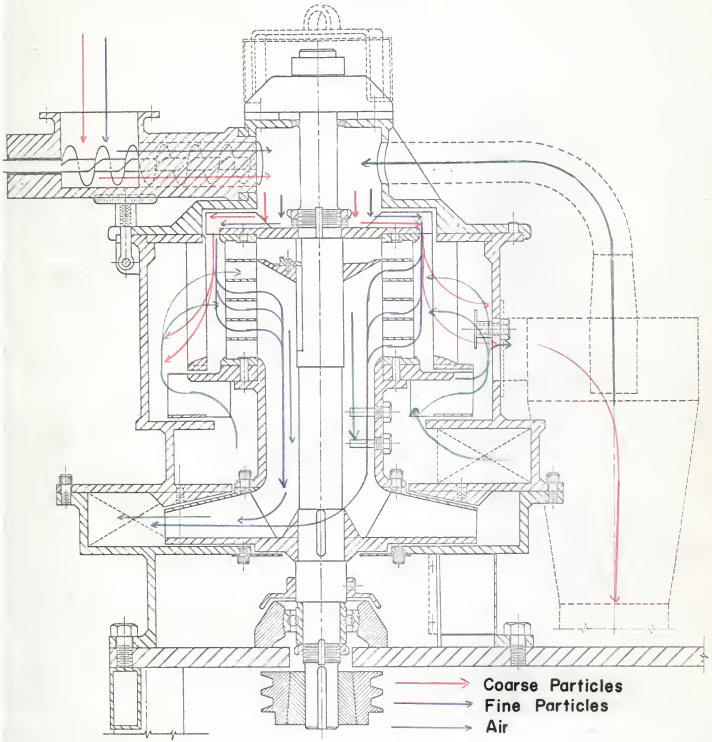


FIG. 4 A cross-sectional diagram of the Classifier

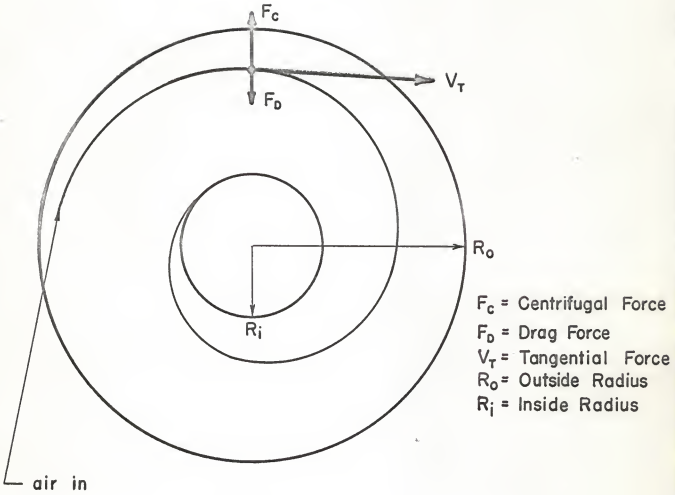


FIG. 5

A theoretical path of a fine particle of flour.

collected. The air, relatively free of particles, was blown into a filter bag by an external fan.

The classifier was driven by a 3 horse power motor operating at 3600 RPM while the fan operated at 3600 RPM with a 1.5 horse power motor. The twin screw feeder with an agitator was driven with a .25 horse power variable speed motor.

Cleaning, Tempering, and Milling

The two wheats used for the protein control procedure were a commercial wheat mix (coded C.P. Mix) and pure Triumph wheat variety.

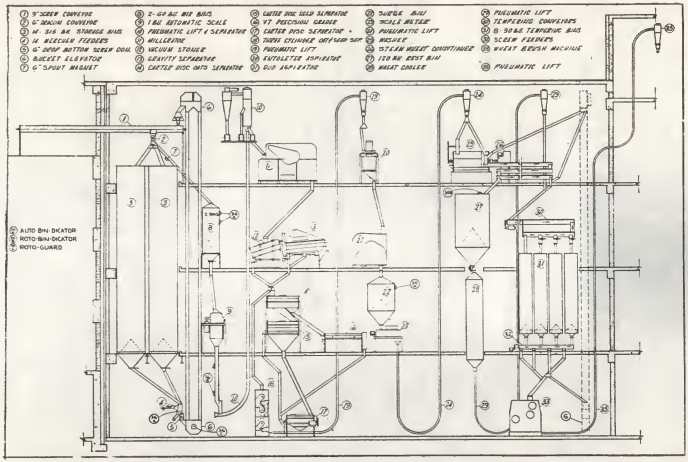
The two wheat samples were cleaned in the Kansas State University Pilot Flour Mill Cleaning House (Fig. 6). The cleaning house flow consisted of a permanent magnet, pneumatic lift aspirator, milling separator, dry stoner separator and gravity table, disc separator, Entoleter-scourer-aspirator and Duo-aspirator. The grain was conveyed pneumatically.

The wheat samples were tempered to 16 per cent moisture and allowed to rest for twenty hours.

The wheat was milled on the Kansas State University Pilot Flour Mill. The flour mill consisted of a five break and ten reduction system (Fig. 7).

The cleaned wheat samples were subjected to physical and chemical tests. Test weight, density, kernel size distribution and 1000 kernel weight were determined.

FIG. 6 Schematic Flow of Kansas State's Grain Cleaning Facilities



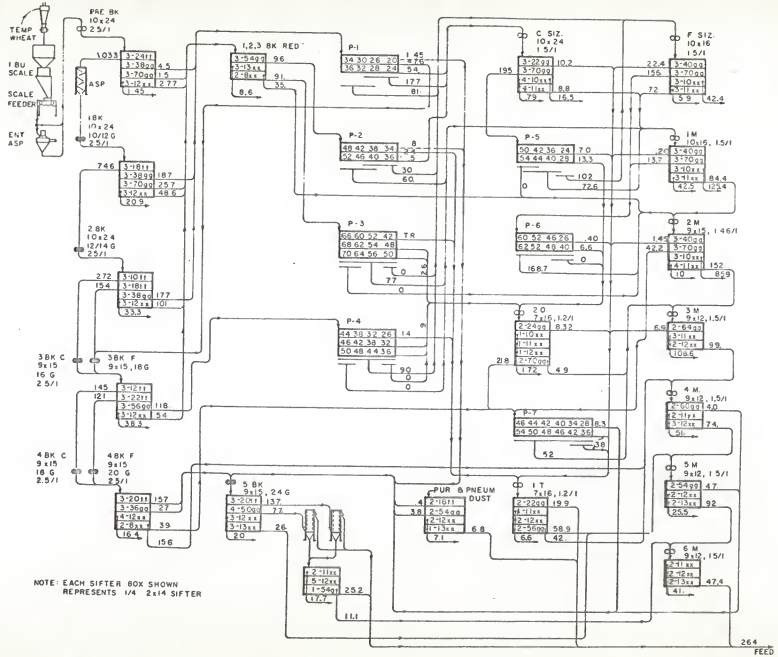


FIG. 7 MILL FLOW

Methods of Analytical Determination

The test weight was run as outlined by U.S.D.A. (9). A thousand kernels were counted and weighed. The liquid density was determined as outlined by Sharp (9). The potential yield was determined as outlined by Shuey (9). The protein, moisture, and ash on all samples were determined by procedure outlined in Cereal Laboratory Methods (9). (Protein and ash are reported on a 14 per cent moisture basis unless otherwise stated.)

Air Classification

The two straight grade flours from the Kansas State University Pilot Mill were air classified in the Hurricane Turbo Air Separator. A four stage classification to produce five fractions was used.

Physical, analytical and baking tests were made on the five fractions plus the parent flour, for both Triumph and Commerical flours as outlined in Cereal Laboratory Methods (9).

They were tested for protein, ash, moisture, maltose, Fisher average particle size, Zeleny sedimentation, Farinograph, Agtron color and bread baking as outlined in Cereal Laboratory Methods (9). Fisher average particle size was determined as outlined by the Fisher Scientific Co. (7, 23, 24).

An amino acid analysis was made on the five fractions of the Commercial Mix and the parent flour. It was reported on a 10 per cent moisture basis. The analysis was determined as

outlined in Model 120B Instruction Manual AIM-2 (36).

After obtaining the protein analysis for the two types of flours, theoretical blends were made to four protein levels: 9.9, 10.7, 11.55, and 13 per cent protein. In making these protein blends all other properties were held as uniform to the parent flour as possible.

Most of the protein shifting was done by either removing or adding the two starchy, low protein fractions. The starchy fractions were added to lower protein and removed to raise the protein content of the flour blends.

Blending Calculations

A simple procedure was used to calculate the protein level of any blend.

(protein content original flour %) x 100 $\pm$ X x (protein content of fraction being added or removed)

= (100 $\pm$ X) x [protein content desired.]

where X is the amount of fraction being added or taken away.

Another way to do this would be to reconstitute the fractions by multiplying the percentage of the fraction by its protein content and then dividing by the total amount used. In this way it could be calculated how much of the starchy fractions were to be taken.

Physical, analytical and baking tests were performed on the blends.

RESULTS AND DISCUSSIONS

Experimental Results

Some preliminary studies were made on the Hurricane Air Separator to standardize the air classification procedure.

Feed rate studies were made with the following classifier settings: 5 decks forward (D.F.), 35° louver curtain (L.C.), at 3600 RPM and with the air inlet wide open. The tests were made using 25 pounds of HRW straight grade flour made on the Kansas State University Pilot Flour Mill. The feed rate was varied from 14.4 pounds/hour to 187.5 pounds/hour. The percentage of pulled-out fines decreased slightly with an increasing feed rate. It was found that the protein content of the fine fraction increased with increased feed rate. The percentage of extracted primary high protein varied from 4 to 7 per cent. The protein content on the amount of the coarse material was not greatly affected with a varying feed rate.

There was a variation in the feed rate depending upon the granularity of the flour.

The protein, ash and moisture determinations were performed as outlined in Cereal Laboratory Methods of the A.A.C.C. (9).

A study was made to determine the most suitable number of fractions. Preliminary studies were made using 5 S.S.S., 6 S.S.S., and 9 S.S.S. fractionations.

The set up for the 4 stage classification to produce five fractions was as follows:

Stage	R.P.M.	Louver Curtain	Decks	Feed Rate
1	5200	10°	6 D.F.	100 lbs/hour
2	5200	10°	6 D.B.	100 lbs/hour
3	3600	10°	2 D.B.	50 lbs/hour
4	3600	35°	2 D.B.	25 lbs/hour

The fractions were tested for protein, ash, moisture and particle size. The protein content for the first fine cut was 27.45%. The lowest protein fraction had 6.7% protein. The coarse fraction had a protein content of 11.48%. The parent flour had 11.3% protein. The ash histogram follows a similar pattern to that of protein. The very fine flour particles collected in the filter bag, though small in quantity, had a protein content of 35.25% and an ash content of .772%.

Fig. 8 shows the protein, ash and particle size distribution of the 5 S.S.S. fractions.

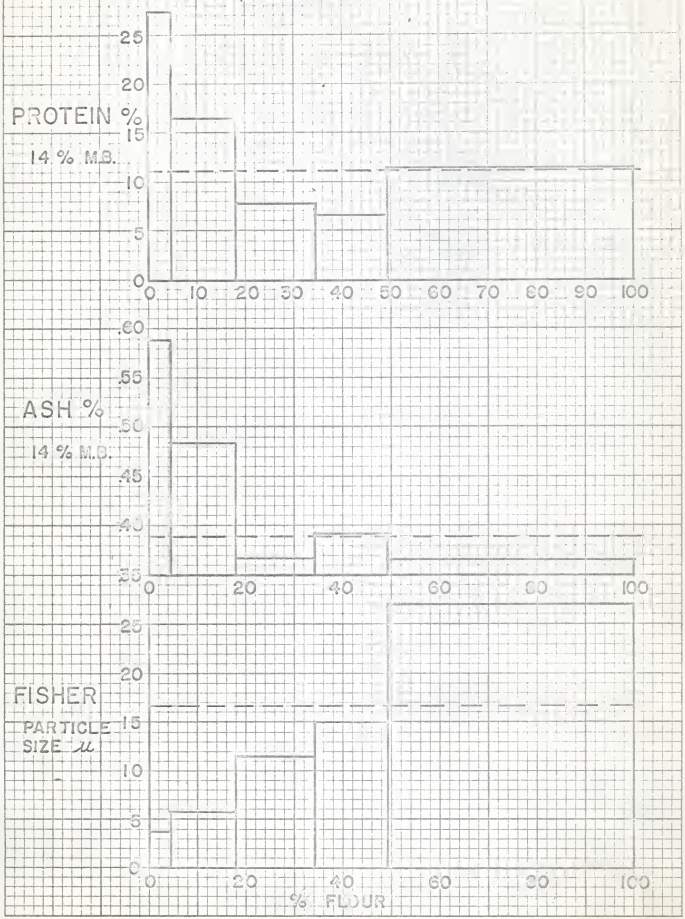
For a five stage fraction to obtain six fractions, the following settings were used:

Stage	R.P.M.	Louver Curtain	Decks	Feed Rate
1	3600	10°	6 D.F.	30-50 lbs/hour
2	3600	10°	3 D.F.	50 lbs/hour
3	3600	10°	6 D.B.	50 lbs/hour
4	3600	35°	6 D.B.	50 lbs/hour
5	3600	35°	6 D.B.	50 lbs/hour

The protein range of the fractions varied from 7.3 to 29.6 per cent starting with a flour protein of 10.1. Approximately 56 per cent of chunks were made. The fractions ranged

FIG. 8

5 S.S.S. FRACTIONS H.R.W. ST GRADE FLOUR



in ash from 0.388 to 0.63 per cent. It was found in this study that a low protein fraction was of a small quantity, approximately 10%, which was not low enough to make the blending procedure practical. Figure 9 shows the protein, ash and particle size distribution of the 6 S.S.S. fractions.

The classifier settings used for the 9 S.S.S. fractionation were as follows:

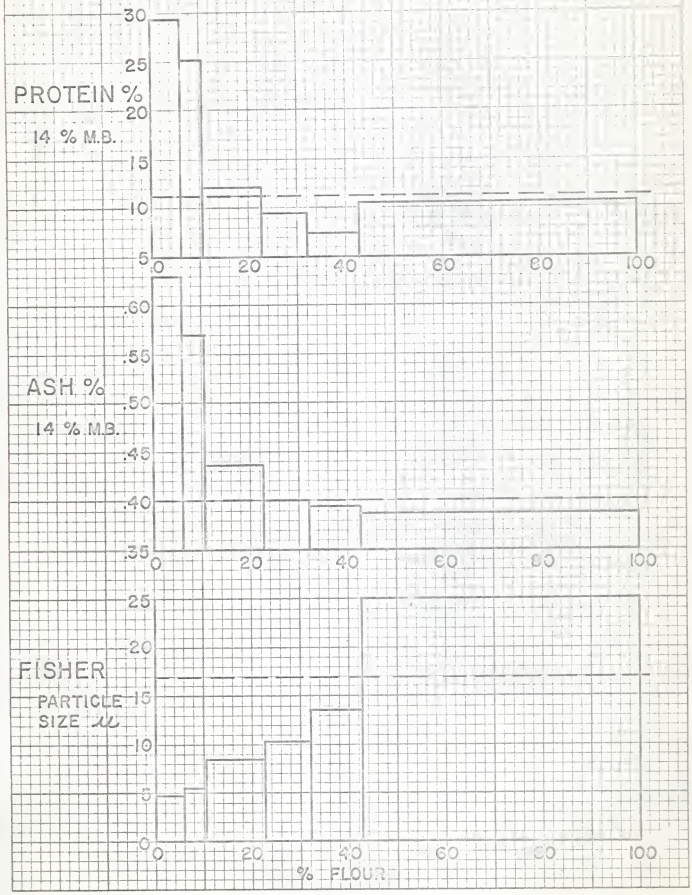
Stage	R.P.M.	Louver Curtain	Decks	Feed Rate
1	5860	10°	6 D.F.	90 lbs/hr
2	5860	10°	6 D.B.	90 lbs/hr
3	5860	10°	6 D.B.	10 lbs/hr
4	3600	10°	6 D.B.	10 lbs/hr
5	2900	10°	6 D.B.	10 lbs/hr
6	2900	10°	4 D.B.	10 lbs/hr
7	2900	10°	2 D.B.	10 lbs/hr
8	2900	35°	2 D.B.	10 lbs/hr

By use of this long procedure it was possible to obtain a wider range of protein levels in the fractions, from 5.6 to 30.5 per cent. This procedure only left 33 per cent of the flour as chunks. From a study of the Whitby Sedimentation Curves it appeared that there was considerable grinding of the flour as it was passed through the classifier. The high speed of classifier and the low feed rate promoted the grinding of the flour in the classifier.

The 9 S.S.S. fractionation is a very long procedure and does not have any added versatility over the 5 S.S.S. fractionation. It gives a number of fractions varying slightly in

FIG. 9

6S.S.S. FRACTIONS H.R.W. ST GRADE FLOUR



10 X 10 PER INCH

protein content.

Protein, ash and particle size data are plotted on Fig. 10. From a comparison of the three preliminary studies made, the 5 S.S.S. classification procedure was found to be most suitable. This gave two high protein fractions, two starchy fractions (low protein) and the chunks. Though it is simple when compared to the 6 S.S.S. or 9 S.S.S. fractionations, the 5 S.S.S. fractions gave a good protein range above and below the parent flour level.

Results With 5 Sub-Sieve Size Procedure

The data obtained on the two wheat samples are shown in Table 1. The Commercial Mix was milled to a 75% while the Triumph wheat was milled to a 76% extraction. Both are based on total products obtained on the Pilot Mill.

The data on the air classification of the Commercial Mix are shown on Table 2, the fractionation procedure in Fig. 11, histograms of protein, Zeleny sedimentation and particle size in Fig. 12, and Agtron color, ash and maltose values in Fig. 13, respectively. The Whitby Sedimentation curves for the fractions are plotted on Fig. 14.

The data for the air classified fractions of the Triumph flour are shown in Table 3, the fractionation procedure in Fig. 15, and histograms of protein, Zeleny sedimentation, and particle size in Fig. 16, Agtron color, ash, and maltose in Fig. 17. The Whitby Sedimentation curves are shown in Fig. 18.

FIG. 10

9 S.S.S. FRACTIONS H.R.W. ST. GRADE FLOUR

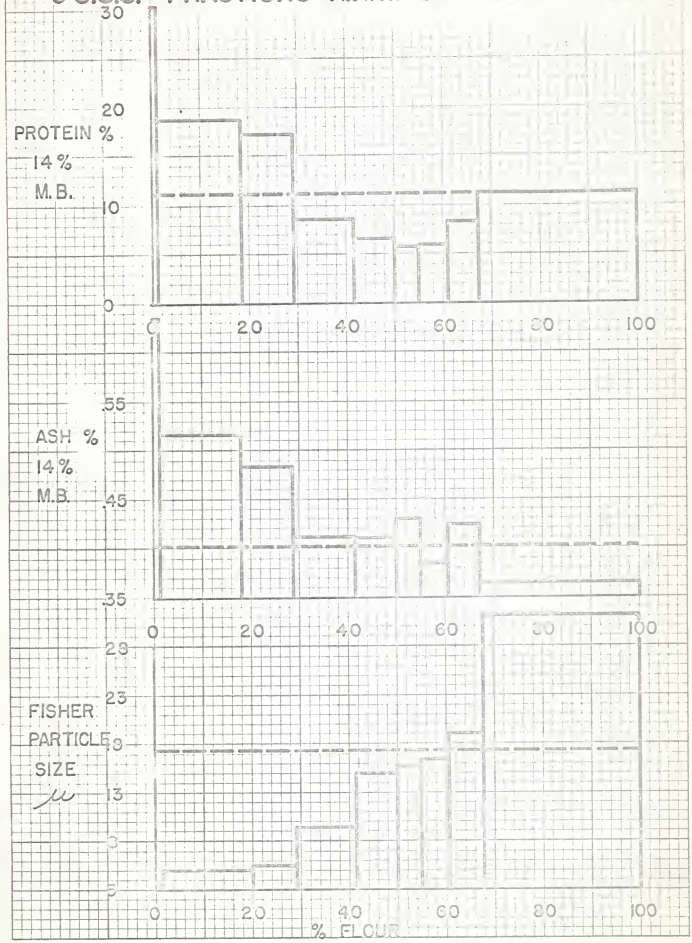


Table 1

	Commercial Mix	Triumph
Test Weight lbs/bu	62.6	61.8
1000 Kernel weight grams	28.61	26.58
Liquid Density Gram/cc	1.487	1.453
Potential Yield %	71.07	74.82
Protein* %	10.81	13.6
Ash* %	1.33	1.624
Moisture %	11.7	10.9

*On 14 per cent moisture basis.

In both the Commercial Mix and the Triumph flour air classified fractions, the protein and ash histograms were similar in appearance. This suggested that high protein was associated with high ash and low protein was associated with low ash. The Fisher average particle size histograms increased from three microns to thirty microns. The Zeleny Sedimentation values followed an inverse relationship to that of particle size.

Table 2

Fraction	Commercial Mix A	B	C	D	E	EE
Percent	100.0	3.7	12.8	17.2	13.8	52.5
Protein*%	9.9	26.3	14.5	6.1	6.6	9.8
Ash*%	0.393	0.614	0.506	0.365	0.392	0.376
Moisture%	12.4	9.0	10.0	10.5	10.1	10.7
Maltose mg/10 g.	135	276	270	207	166	101
Fisher Particle Size	19.4	3.0	5.5	11.1	14.5	27.8
Zeleny Sedimentation cc	40	77	76	70	65	36
Absorption%	63	110	85	63	61	62
Agtron Color% 60.5-95.0	61	65	64	70	67	58
Valorimeter	81	100.+	94	47	42	72
MTI	40	3	12	85	60	35
Loaf Volume cc	2910	3000	3000	1875	1725	2810
Total Score	86	73	86	41	38	87

*On 14% M.B.

FIG. 11 566 LAB SIZE CLASSIFIER COMMERCIAL MIX

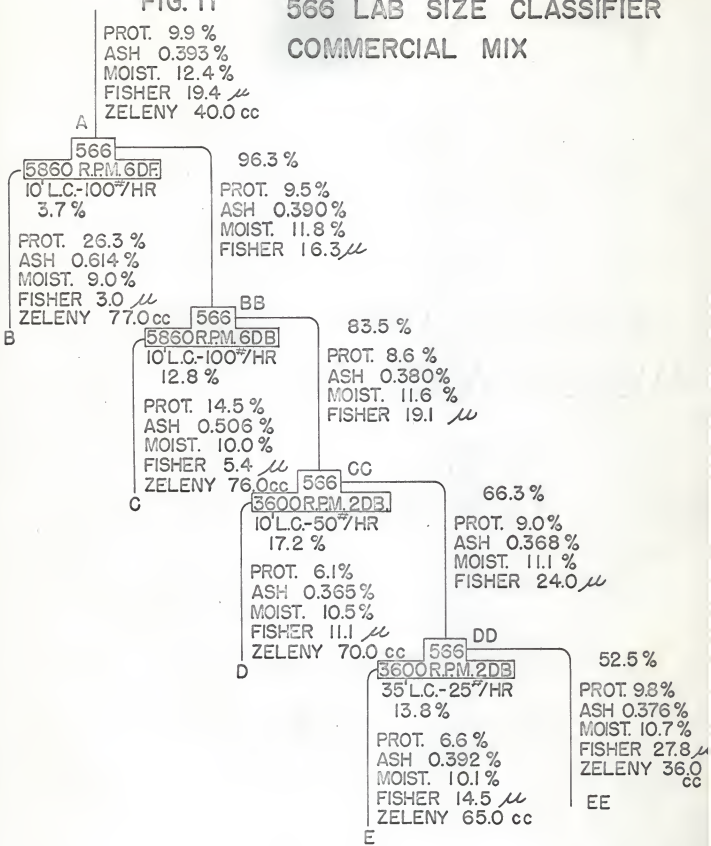


FIG. 12

AIR CLASSIFIED FLOUR FRACTIONS

COMMERCIAL MIX

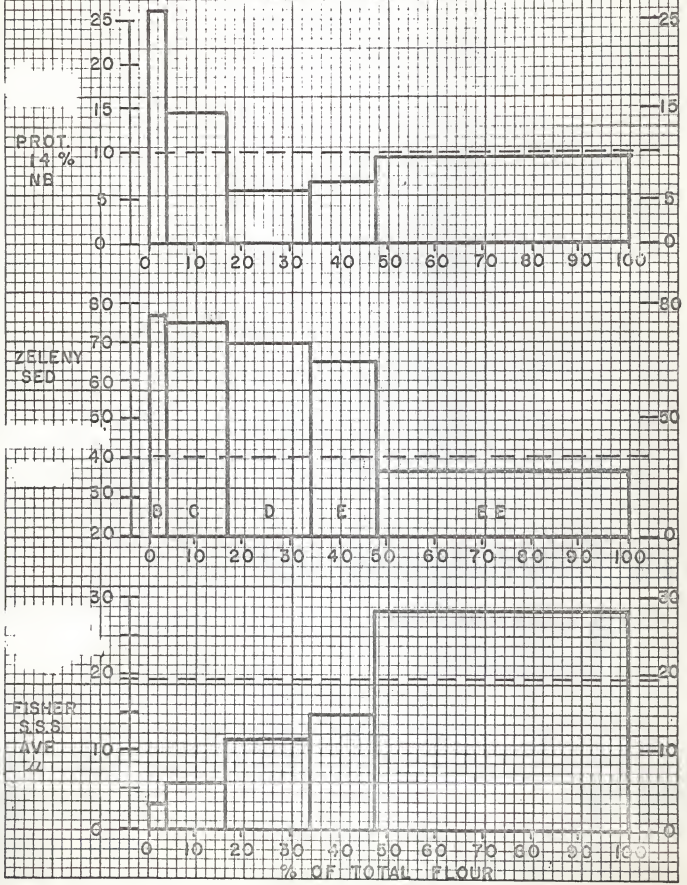
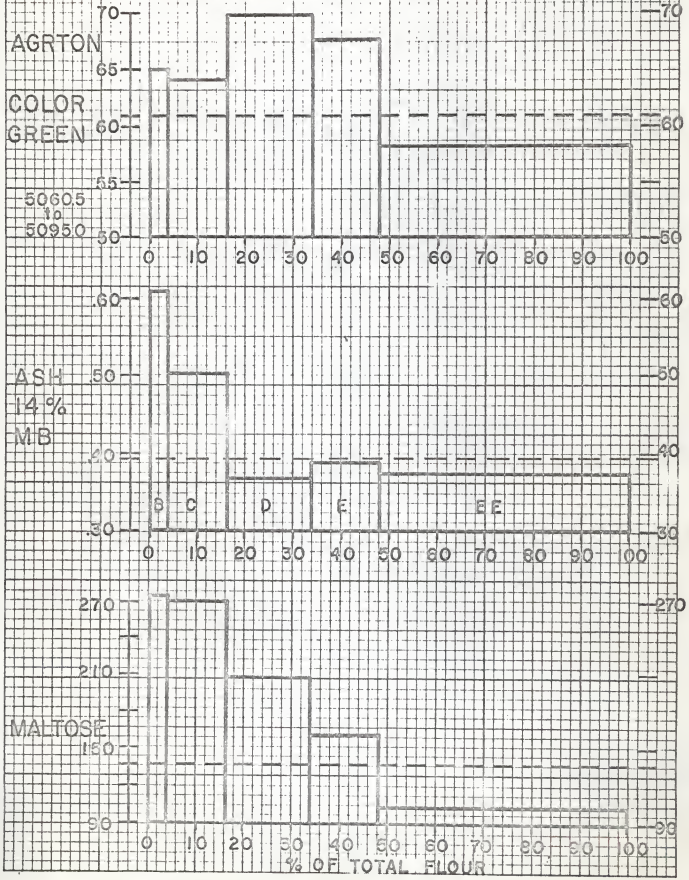


FIG. 13

AIR CLASSIFIED FLOUR FRACTIONS

COMMERCIAL MIX



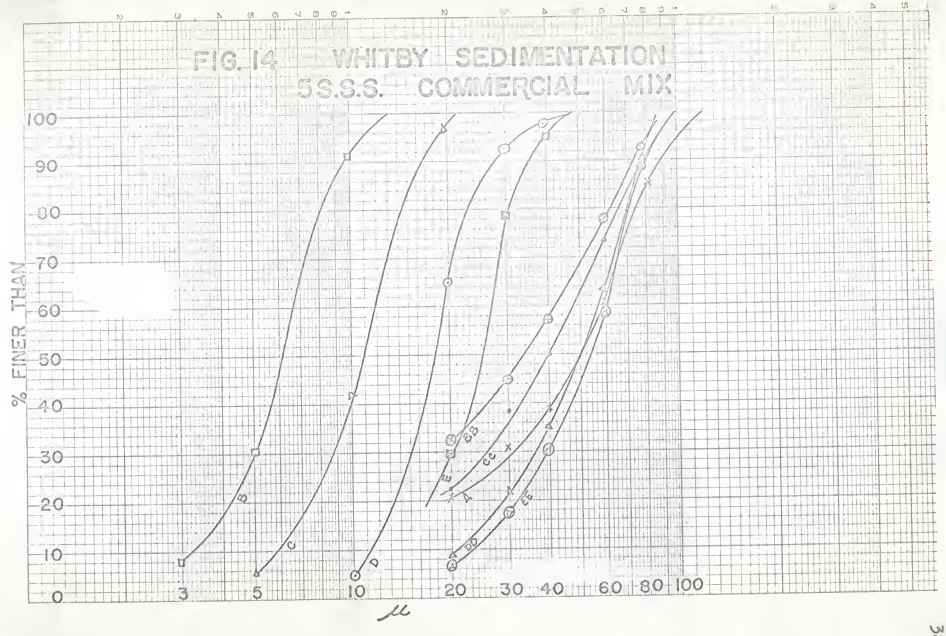


FIG. 14 WHITBY SEDIMENTATION
5 S.S.S. COMMERCIAL MIX
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
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Table 3

Fraction	Triumph A	B	C	D	E	EE
Percent	100.0	3.6	12.5	17.7	14.7	51.5
Protein*%	11.5	24.2	18.4	6.9	6.9	10.8
Ash*%	0.382	0.586	0.505	0.417	0.399	0.379
Moisture%	12.9	10.4	9.7	11.2	11.6	11.5
Maltose mg/10 g.	135	244	2.5	191	126	80
Fisher Particle Size	18.5	3.2	5.3	12.1	16.2	29.0
Zeleny Sedimentation cc	43	74.2	75.1	65	61	37.9
Absorption%	59.6	104.0	83.6	58.0	55.4	59.2
Agtron Color% 60.5-95.0	69	70	73	76	75	63
Valorimeter	49	97	83	14	14	54
MTI	45	35	20	130	150	55
Loaf Volume cc	2850	3000	3000	2250	1960	2885
Total Score	90	68	84	59	43	81

*On 14% M.B.

FIG. 15 566 LAB SIZE CLASSIFIER TRIUMPH ST. GRADE FLOUR

PROT. 11.55 %
ASH .382 %
MOIST. 12.9 %
FISHER 18.5 μ
ZELENY 43.0 cc

A

566
5860 R.P.M. 6DF.
10' L.C.-100#/HR
3.6 %

PROT. 24.2 %
ASH .586 %
MOIST. 10.4 %
FISHER 3.2 μ
ZELENY 74.2 cc

B

96.4 %
PROT. 10.35 %
ASH .391 %
MOIST. 12.0 %
FISHER 17.9 μ

BB

566
5860 R.P.M. 6DB.
10' L.C.-100#/HR
12.5 %

PROT. 18.4 %
ASH .505 %
MOIST. 9.7 %
FISHER 5.3 μ
ZELENY 75.1 cc

C

83.9 %
PROT. 9.23 %
ASH .369 %
MOIST. 11.5 %
FISHER 20.0 μ

CC

566
3600 R.P.M. 2DB.
10' L.C.-50#/HR
17.7 %

PROT. 6.91 %
ASH .417 %
MOIST. 11.2 %
FISHER 12.1 μ
ZELENY 65.0 cc

D

66.2 %
PROT. 9.8 %
ASH .380 %
MOIST. 11.7 %
FISHER 24.0 μ

DD

566
3600 R.P.M. 2DB.
35' L.C.-25#/HR
15.7 %

PROT. 6.93 %
ASH .399 %
MOIST. 11.6 %
FISHER 29.0 μ
ZELENY 61.0 cc

E

51.5 %
PROT. 10.8 %
ASH .379 %
MOIST. 11.5 %
FISHER 37.9 μ

EE

FIG. 16

AIR CLASSIFIED FLOUR FRACTIONS

TRIUMPH

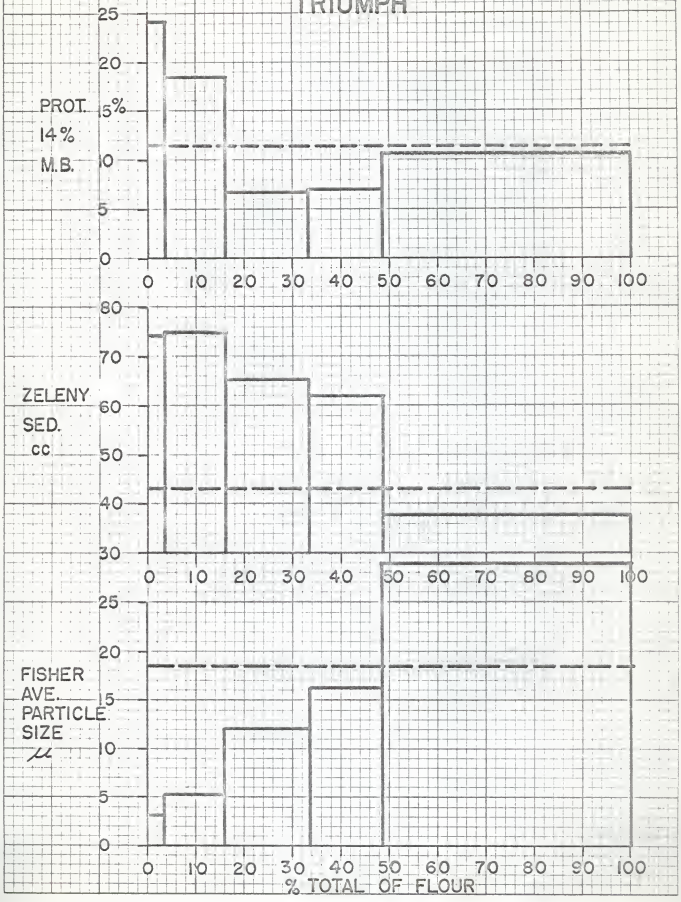
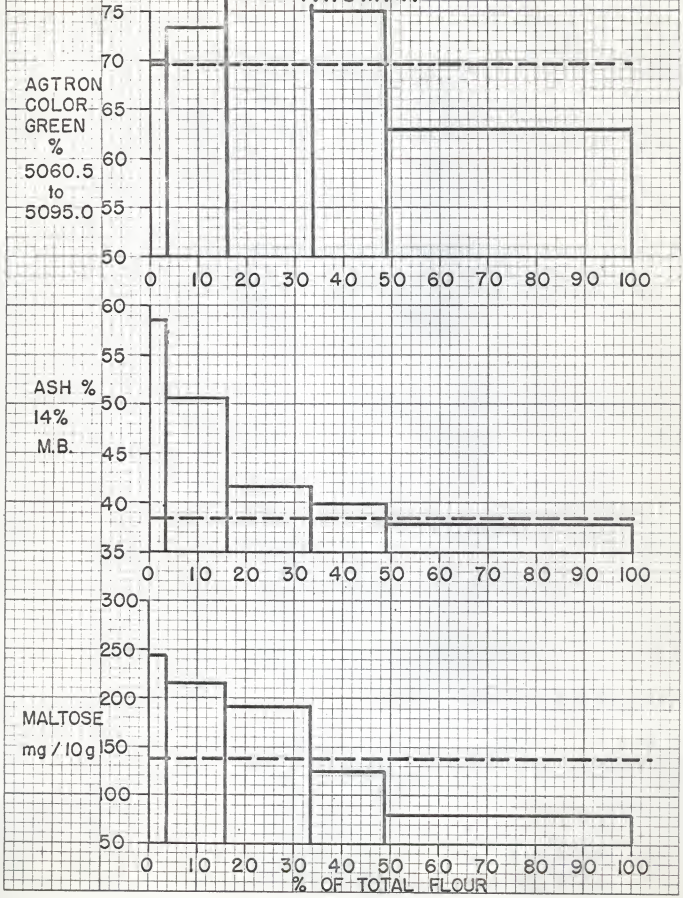


FIG. 17

AIR CLASSIFIED FLOUR FRACTIONS



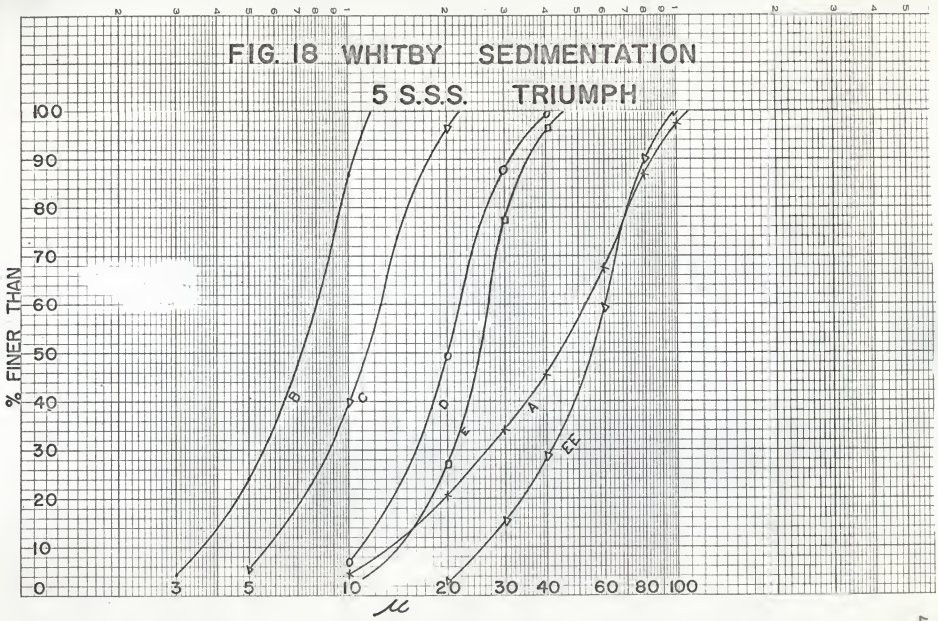


FIG. 18 WHITBY SEDIMENTATION
5 S.S.S. TRIUMPH
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
μ
B
C
D
E
A
EE

The Zeleny Sedimentation value for the first four fractions, which are the high protein and the starchy fractions, did not give a clear sediment, making it difficult to decide what value was to be reported. There were two possible points of sediment formation, one was close to 60 cc. and the other 20 cc. The value near 60 was reported. After a few more minutes had elapsed there was a very clear sediment at approximately 20 cc.

The maltose values increased with decreasing particle size. The finer the flour, the higher the maltose value. This is what would be expected since fine flour would contain a lot of ruptured starch. The coarse flour had less damaged starch.

Absorption of flours varied with protein content. A high protein content was associated with high absorption. The absorption for the primary high protein fraction was 110 per cent into 53 minutes mixing time, making the baking difficult.

With conventionally milled flours the higher the color value, the whiter the flour. On the Agtron colormeter, using Bulk Flour (not in a slurry) there was a relationship between color and ash content. However, for air separated fractions the color does not follow the ash content because of the fine particle size and uneven surface. This resulted in a higher color reading for the fine fractions than the chunks. The chunks were comparatively granular and did not offer good reflectance. On regrinding the chunks the color value would improve a great deal. Regrinding would also raise the maltose

value of the chunk fraction.

The fine fraction of both the Commercial Mix and Triumph, along with the parents, were baked. A photograph of the breads are shown on Figs. 19 and 20. The bread of the high protein fraction of the Commercial Mix collapsed before the photograph was taken. It was thus shown in ink at about the shape it was when baked.

The Farinograph curves of the five fractions of the two wheats along with the parents are shown in Figs. 21 and 22. The primary high protein fraction had extremely long curves with high absorption and long mixing time. The two starchy fractions had short Farinograph curves. The Farinograph mixing time was one minute for each of these low protein fractions. The Farinograph curves of the starchy fraction looked very similar to those of soft wheat flours. The two starchy fractions made good cake flours. The starchy fractions were very similar to soft wheat flours. Further investigation of the starchy fractions should prove worthwhile.

The loaf volumes were directly related to the protein contents of the fractions. The breads were scored giving no consideration to the fact that they were air classified fractions.

The secondary high protein fraction, along with the parent and the chunks, baked fairly well. The primary high protein gave a large loaf but collapsed on cooking. Starchy or low protein fractions baked poorly.

Fig. 19. Breads of 5 S.S.S. fractions along with the parent flour of the Commercial Mix flour.

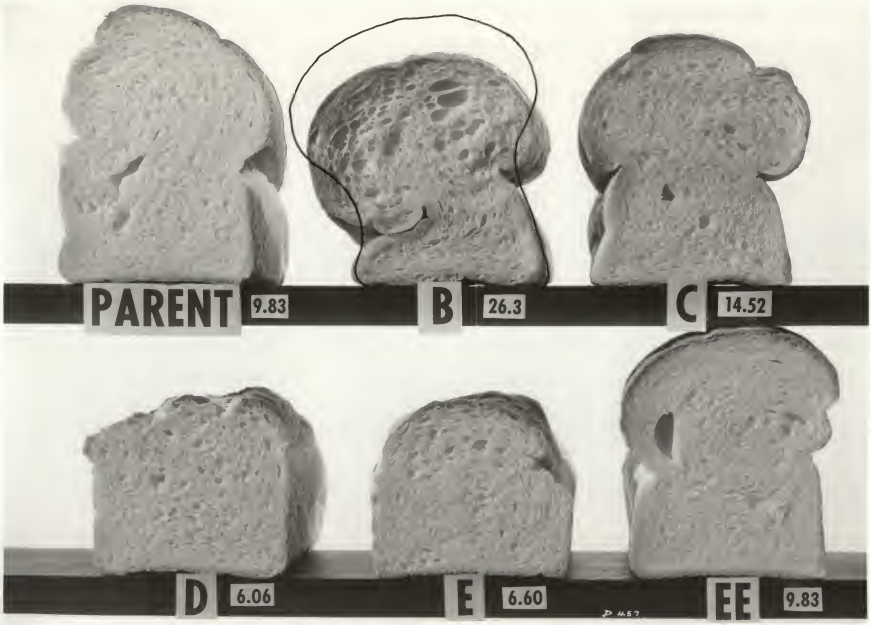
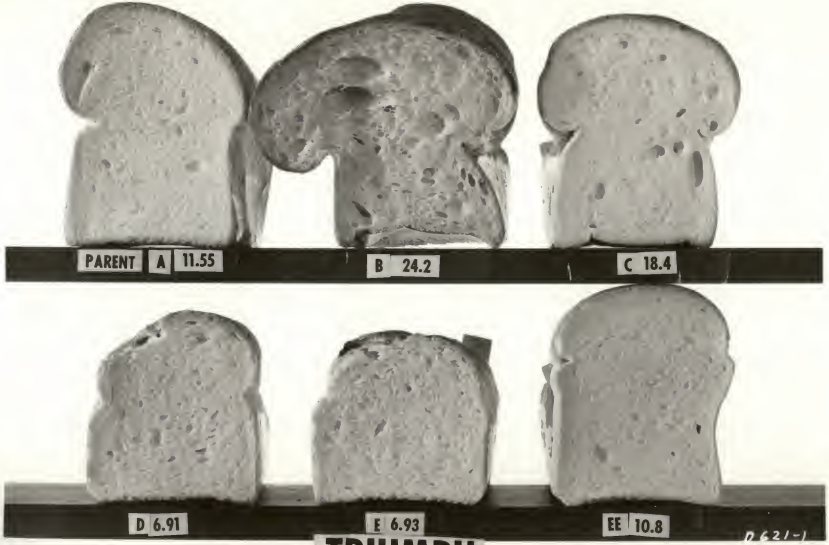

PARENT
9.83
B
26.3
C
14.52
D
6.06
E
6.60
EE
9.83
P 467

Fig. 20. Breads of 5 S.S.S. fractions along with the parent flour of the Triumph.


PARENT A 11.55
B 24.2
C 18.4
D 6.91
E 6.93
EE 10.8
D 621-1
TRIUMPH

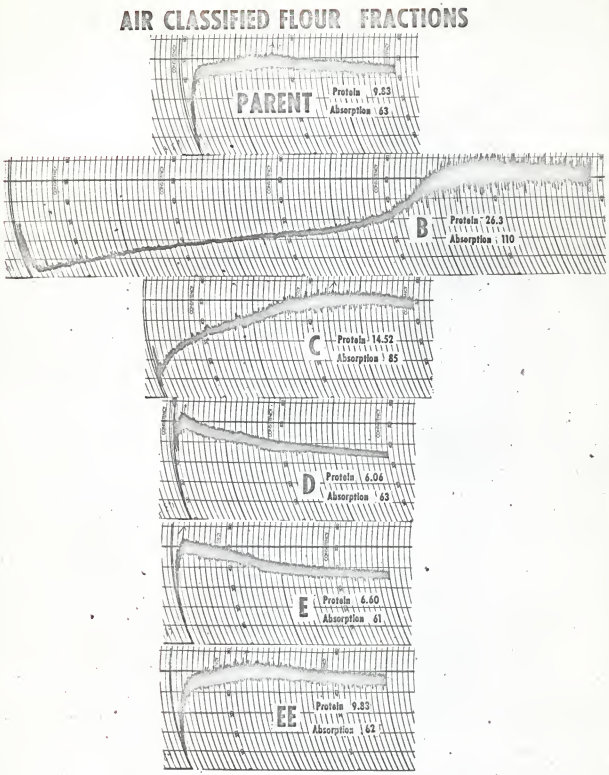


FIG. 21 Farinograph curves for 5 S.S.S fractions of Commercial Mix

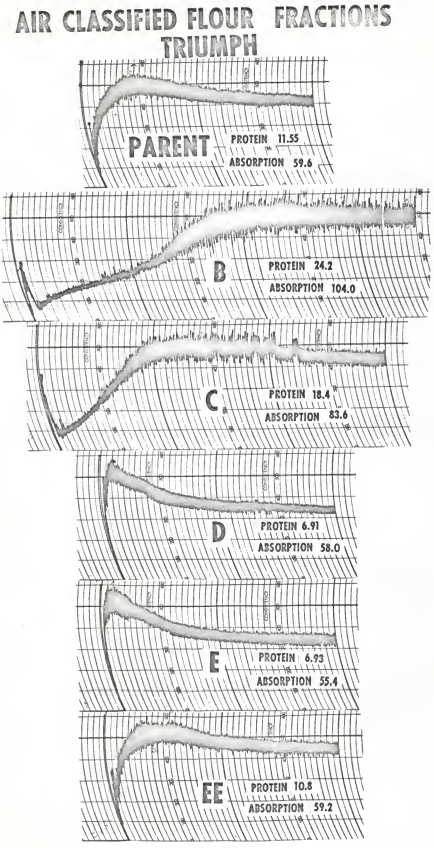


FIG. 22 Farinograph curves for 5 S.S.S. fractions of Triumph

Amino acid distribution in the five fractions of the Commercial Mix are reported on Table 4 and Figs. 23, 24, 25, 26, and 27 on a per per cent protein basis. Since there was not enough data collected for a statistical analysis to be significant it was not performed.

The results indicated that the protein of the primary high protein fraction (B) had greater per per cent in Glutamic Acid, cystine, tyrosine, serine, and Phenylalanine than the other fractions. Threonine, lysine, and alanine were present in greater amounts in the starchy fractions. The other amino acids, though varying per protein, were not especially concentrated on any one fraction.

A statistical analysis on the data for the air classified fraction showed (Table 5) no partial correlation between maltose and Zeleny Sedimentation with Fisher Particle Size constant. A significant protein correlation was indicated between Maltose and Fisher Particle Size and also between Zeleny Sedimentation and Fisher Particle Size. There was a highly significant correlation between Zeleny Sedimentation and Fisher Particle Size with protein content. While slightly significant correlation was indicated between protein and Fisher Particle Size, there was a significant correlation between protein and loaf volume.

Table 4

Amino Acid distribution in 5 fractions
Commercial Mix

Fraction	A	B	C	D	E	EE
Lysine	1.9	2.2	2.2	2.3	2.3	1.7
Histidine	1.9	2.2	1.9	2.2	2.2	2.4
Ammonia	3.7	2.0	4.8	4.2	4.2	3.9
Arginine	2.9	3.7	3.4	3.3	3.2	3.1
Aspartic Acid	3.6	4.1	5.0	4.6	4.3	4.0
Threonine	2.4	2.7	2.9	3.3	2.8	2.7
Serine	4.2	5.1	5.4	4.3	4.1	9.6
Glutamic Acid	34.7	42.4	38.5	36.4	37.1	39.0
Proline	10.8	13.4	12.9	12.8	12.4	12.3
Glycine	3.2	3.7	3.8	3.7	3.7	3.5
Alanine	2.7	3.1	3.1	3.3	3.5	3.0
Half Cystine	2.3	4.6	2.9	2.2	2.0	2.7
Valine	4.0	4.6	4.7	4.7	4.6	4.9
Methionine	1.3	1.6	1.5	1.5	1.4	1.5
Isdeucine	3.4	9.1	4.0	4.0	3.8	38.4
Leucine	6.4	7.7	7.7	7.6	7.0	7.2
Tyrosine	1.9	3.2	1.9	1.8	1.7	1.7
Phenylalanine	4.7	5.8	5.5	5.4	5.0	5.3
Crude Protein	10.2	26.3	14.5	6.1	6.6	9.8

All data reported in per cent of protein on 10% M.B.

FIG. 23 AMINO ACIDS OF 5 S.S.S. COMMERCIAL MIX

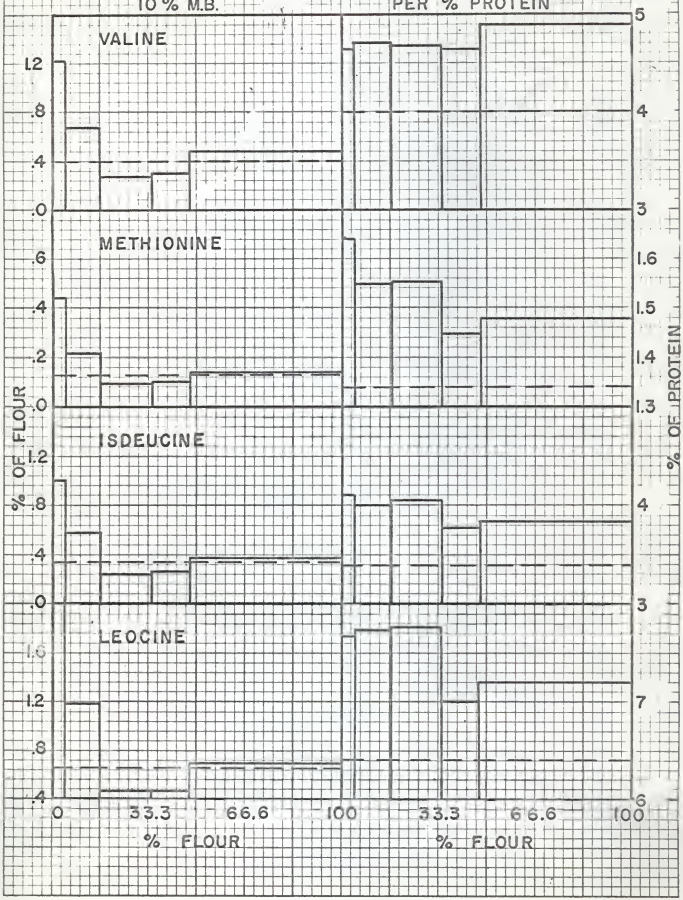


FIG. 24

AMINO ACIDS OF 5S.S.S. FRACTIONS

COMMERCIAL MIX

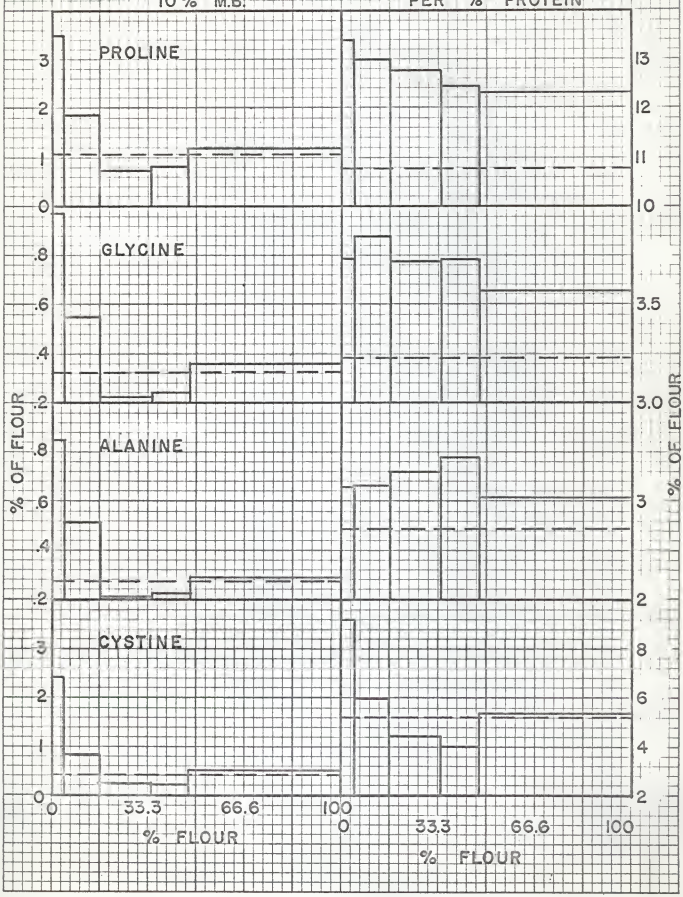


FIG. 25

AMINO ACIDS OF 5S.S.S FRACTIONS

COMMERCIAL MIX

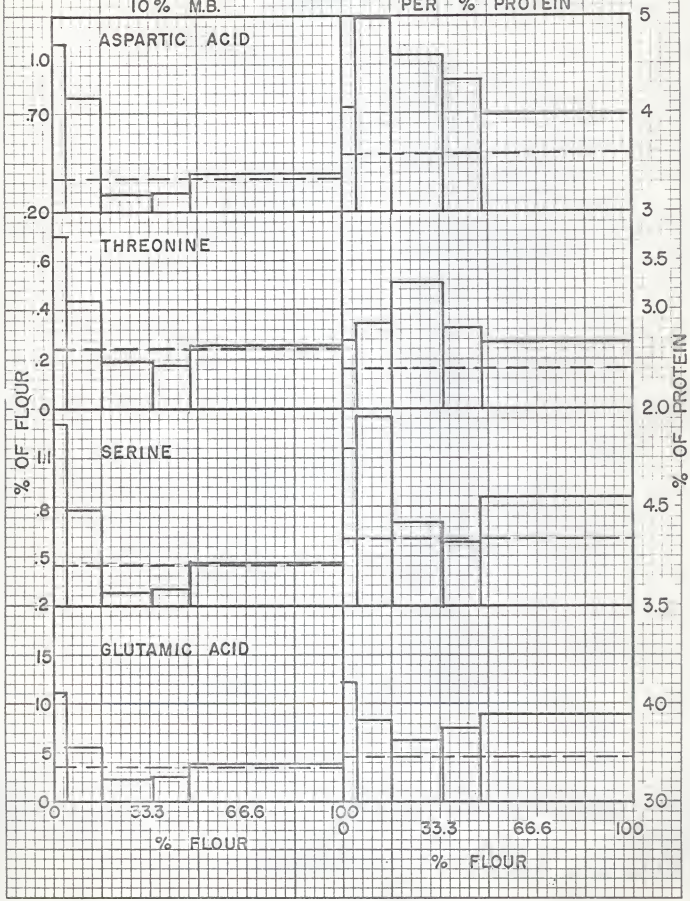


FIG. 26

AMINO ACIDS OF 5 S.S.S. COMMERCIAL MIX

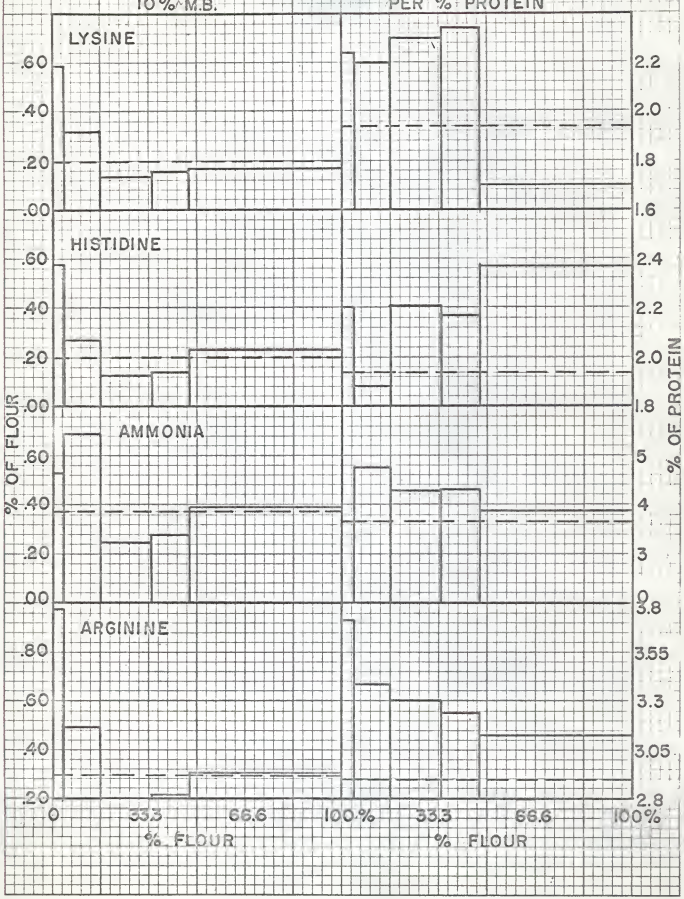


FIG. 27

AMINO ACIDS OF 5 S.S.S. COMMERCIAL MIX

10 % M.B. PER % PROTEIN

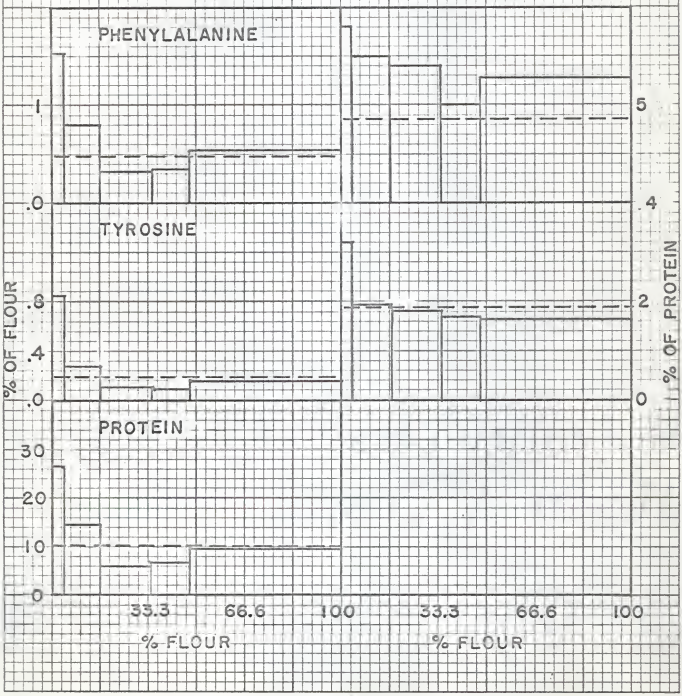


Table 5

Partial correlation for air classified fractions	Correlation Coefficient Commercial Mix	Triumph
Between Maltose and Zeleny Sedimentation with Fisher Particle Size constant	0.04	-0.24
Between Maltose and Fisher Particle Size with Zeleny Sedimentation constant	-0.83	-0.85
Between Zeleny Sedimentation and Fisher Particle Size with Maltose constant	-0.50	-0.68
Between Protein and Zeleny Sedimentation with Fisher Particle Size constant	-0.52	-0.37
Between Protein and Fisher Particle Size with Zeleny Sedimentation constant	-0.65	-0.56
Between Zeleny Sedimentation and Fisher Particle Size with Protein constant	-0.95	-0.93
Direct correlation between Protein and Loaf Volume	0.66	0.77

Flour protein blends were made using Method A and B, except for the high protein blend (13% protein) from the Commercial Mix (low protein). To make the 13% protein blend, both the starchy fractions were removed and a small portion of the primary high protein fraction added. This procedure of blending did not produce poor results in baking, however, it is not considered the most desirable.

The Commercial Mix high protein blend (4) was obtained by

using Method C. Table 6 shows that the high protein blend (13%) had a very high absorption, high Zeleny Sedimentation value, high ash value and that it was much finer than the original flour.

The physical, analytical and baking data for the blends are shown on Table 6. For both the Commercial Mix and the Triumph flour blends, the analytical values were very close to the theoretical values. Except for the high protein blends in both flours, the properties of the blends were reasonably close to those of the parent flours. The values on the high protein (13% protein) blends were considerably different to those of the parent.

Figures 28, 29, and 30 show the physical and baking characteristics of the blends. In very broad terms for the blends as the protein level raised, ash also increased. Zeleny Sedimentation values increased steadily with protein content, while particle size decreased with high protein level.

Loaf volume increased with protein content, as did the total score. The absorption value also increased as the protein level was raised. The Mixing Tolerance Index (MTI) decreased in value with increasing protein content.

Table 6

	Blends							
	Commercial Mix				Triumph			
	Blend 1	Blend 2	Blend 3	Blend 4	Blend 1	Blend 2	Blend 3	Blend 4
Protein*%	9.9	10.6	11.6	12.9	9.8	10.4	11.5	13.1
Ash*%	0.393	0.402	0.409	0.410	0.381	0.382	0.383	0.416
Moisture%	12.4	10.1	11.7	11.8	11.9	12.1	12.9	11.0
Maltose mg/10 g.	135	201	140	140	121	126	135	121
Fisher Particle Size micron	20.0	13.8	15.4	12.5	17.4	17.7	18.1	14.7
Zeleny Sedimentation cc	30.44	31.8	30.1	34.0	35.0	39.0	43.0	47.0
Absorption%	63	65	64	66.8	57.2	57.6	59.6	67.4
Agtron Color% 60.5-95.0	71	72	71	70	71	72	70	63
Valorimeter	81	70	74	82	40	49	49	60
MTI	40	60	25	20	60	60	45	25
Loaf Volume cc	2625	2800	2850	2910	2760	2860	2850	3000
Total Score	66	77	75	79	79	81	90	86

*On 14 per cent Moisture Basis.

FIG. 28
FLOUR PROTEIN BLENDS

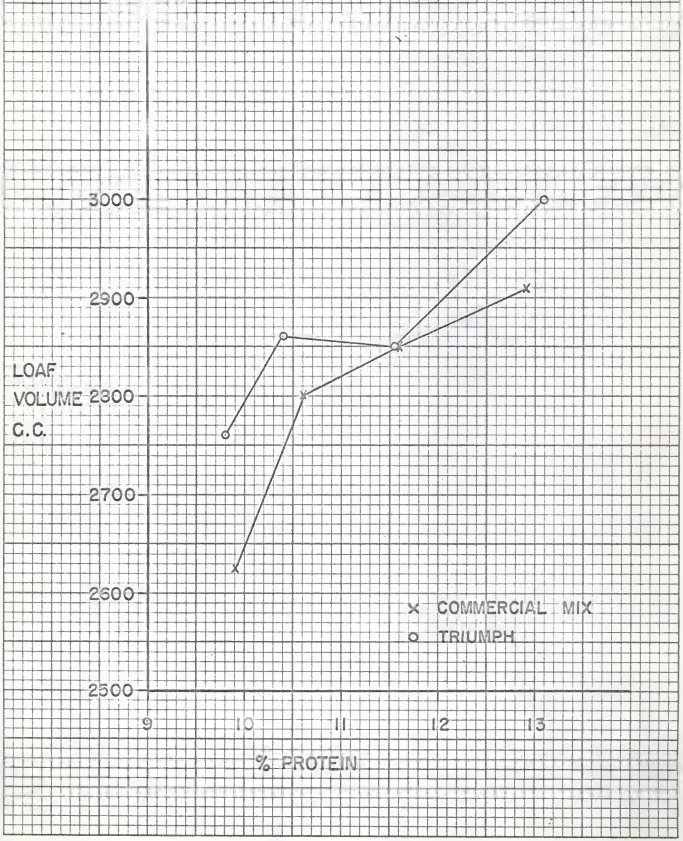


FIG. 29
FLOUR PROTEIN BLENDS

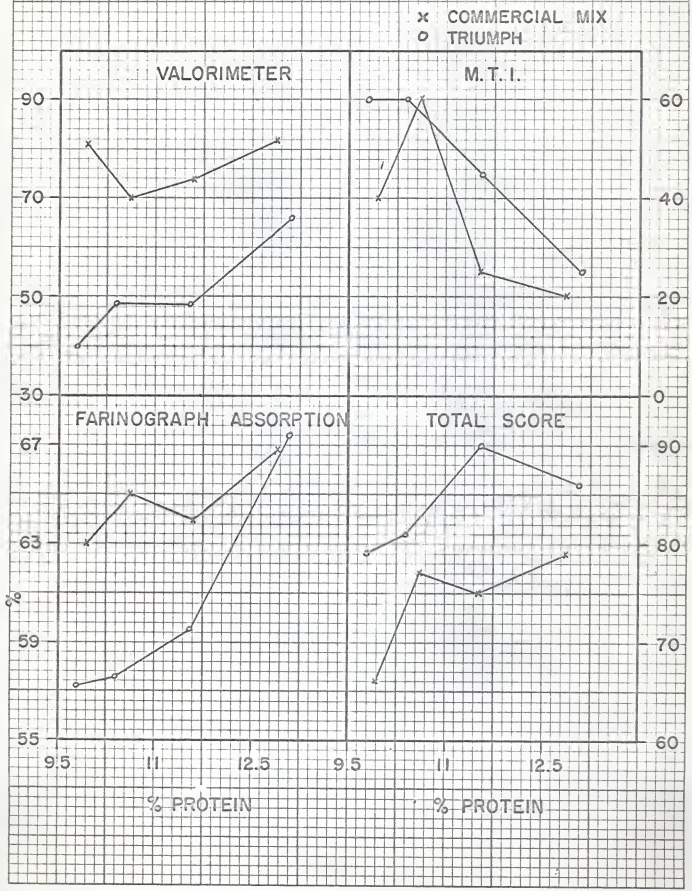
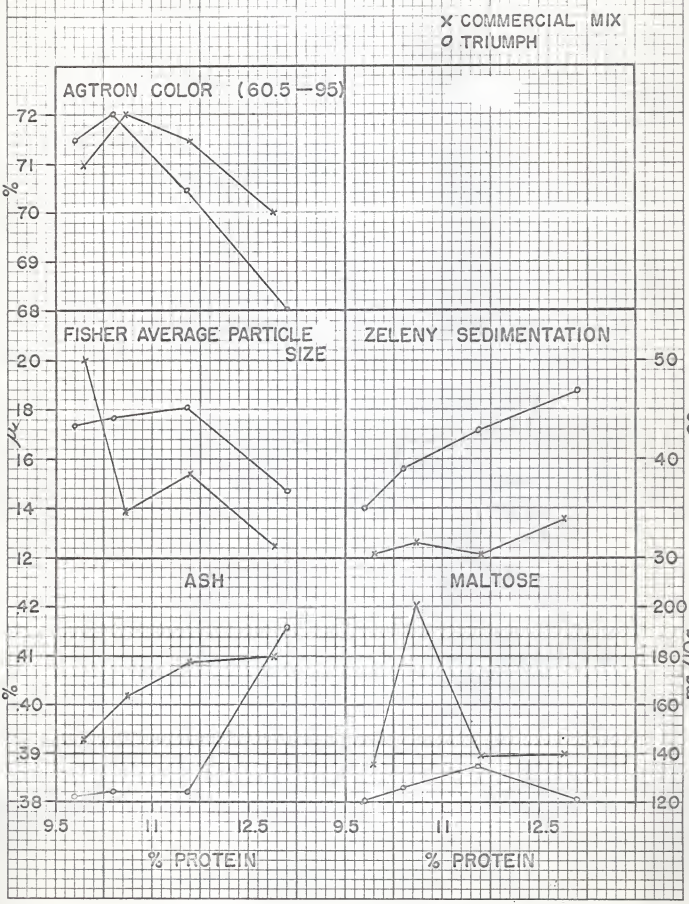


FIG. 30
FLOUR PROTEIN BLENDS



Figures 31 and 32 give the Whitby sedimentation particle size distribution of the protein blends. A comparison of the particle size distribution was made after the Commercial Mix was blended to the same protein level as the Triumph in Fig. 33. Triumph blended to the protein level of the Commercial Mix were compared in Fig. 34. Blended flours may have more of the fine particles or coarse particles than the flour did in its original form. When most of the starchy fractions have been removed, the resulting flour lacks particles in the 20 to 40 micron range. This gave a flour consisting largely of flour particles larger than 40 microns and smaller than 20 microns.

The four blends from each flour when baked, showed a steady improvement in loaf volume, and total score, on increasing protein content.

The Farino graph curves and bread of the blends 1, 2, 3, and 4 are compared in Figs. 35 and 36 respectively. For equal protein content, the Triumph seemed to bake better. The bread baking properties improved as protein content increased. There was also a considerable improvement in the Commercial Mix with increasing protein content.

In the normal evaluation procedure, Blend 1 (9.9 protein) of the Commercial Mix would have been compared with Blend 3 (11.55 protein) of the Triumph flour. On comparison of those two, the Commercial Mix bread, without question, would have been judged at a disadvantage because of its low protein. When the protein is brought to a common level, a better evaluation should be possible. Blend 3 of the Commercial Mix

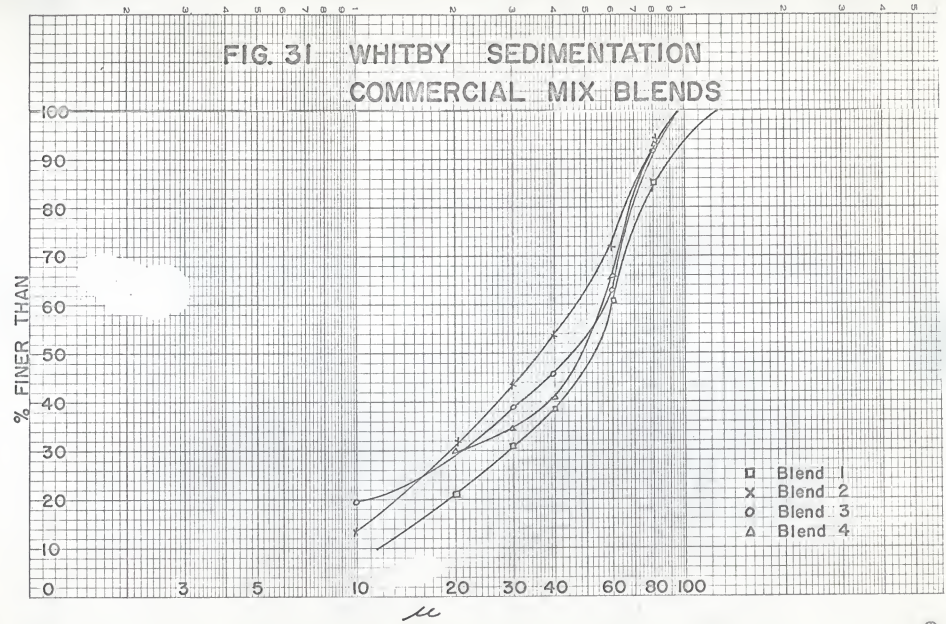


FIG. 31 WHITBY SEDIMENTATION
COMMERCIAL MIX BLENDS
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
μ
Blend 1
Blend 2
Blend 3
Blend 4

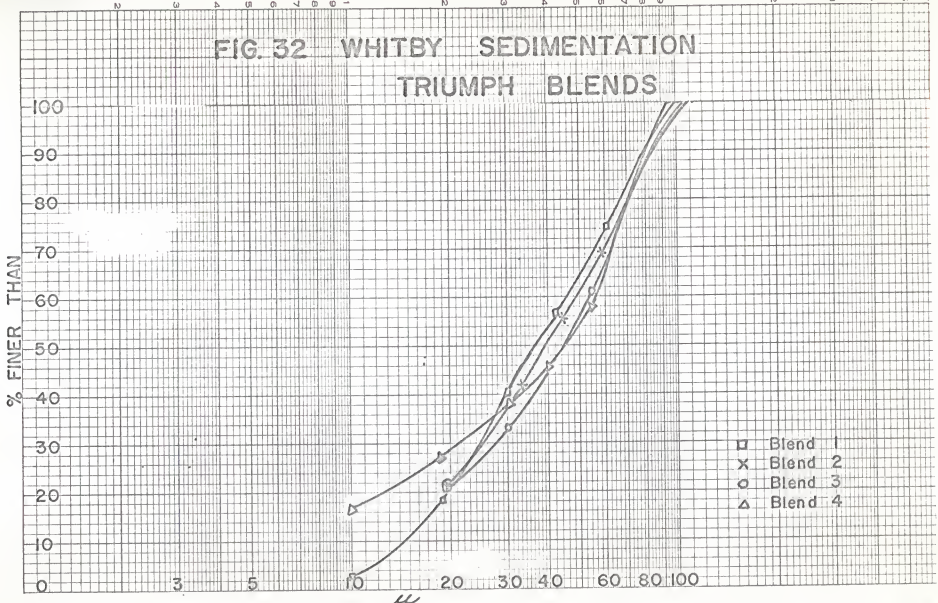


FIG. 32 WHITBY SEDIMENTATION
TRIUMPH BLENDS
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
μ
Blend 1
Blend 2
Blend 3
Blend 4

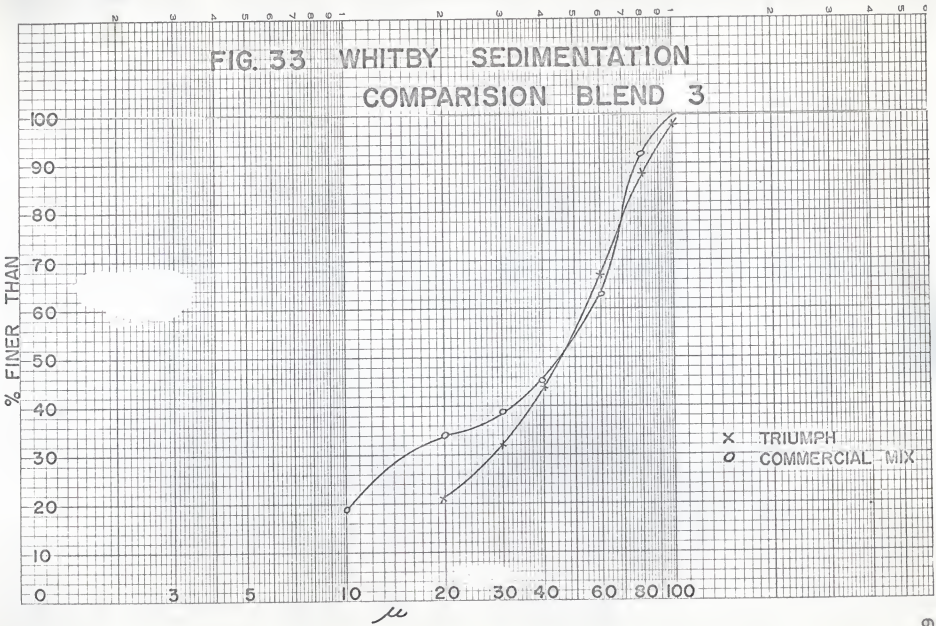


FIG. 33 WHITBY SEDIMENTATION
COMPARISION BLEND 3
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
μ
X TRIUMPH
O COMMERCIAL MIX

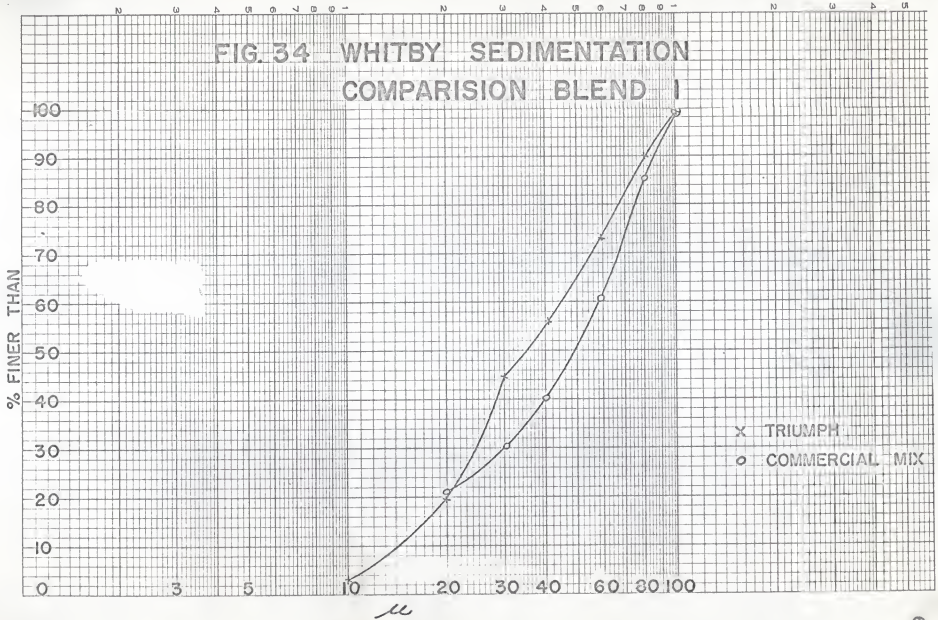


FIG. 34 WHITBY SEDIMENTATION
COMPARISION BLEND I
% FINER THAN
100
90
80
70
60
50
40
30
20
10
0
3
5
10
20
30
40
60
80
100
μ
X TRIUMPH
o COMMERCIAL MIX

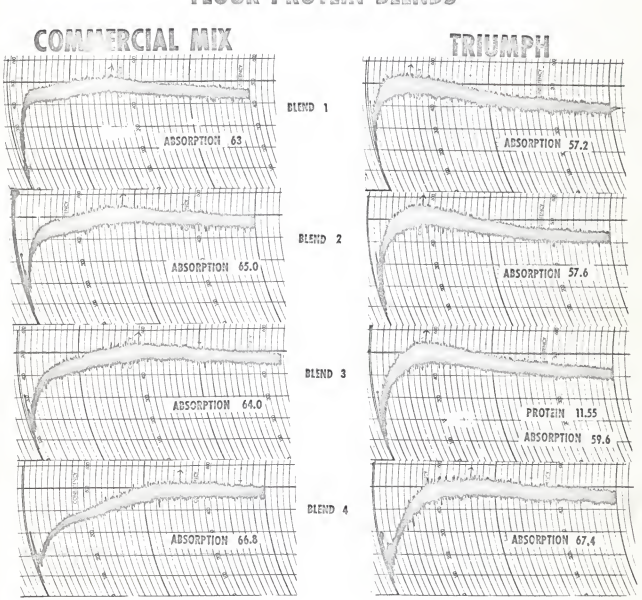


FIG. 35 Comparison of Farinograph curves for the blends

Fig. 36. A comparison of the breads baked of the flour protein blends from the Commercial Mix and Triumph Wheat flours.

Blend 1	9.9
Blend 2	10.7
Blend 3	11.5
Blend 4	13.0


FLOUR PROTEIN BLENDS
BLEND 1
2
TRIUMPH
3
4
COMMERCIAL MIX

(11.6 protein) compares much more favorably with the parent triumph (11.55 protein) than did the parent Commercial Mix. The routine bread baking evaluating procedure could be made far more useful if all the flour being evaluated were of the same protein content. A direct correlation between protein content and loaf volume indicated a highly significant correlation ($r = 0.92$).

CONCLUSIONS

Two or more wheats of different protein levels when subjected to evaluation have an inherent disadvantage because of variation in protein content. By bringing two wheats to the same protein level, it was observed that the baking characteristics were more closely comparable than when the protein levels were different. Since protein quantity plays such an important part in baking, the evaluation of protein quality is difficult with variable protein levels.

As seen from the results with uniform protein, a better evaluation of quality would be possible.

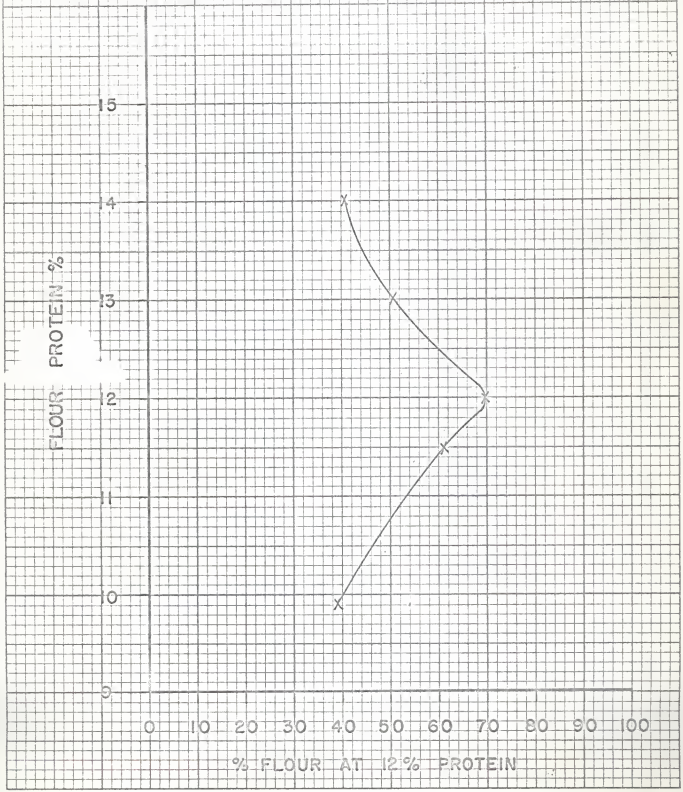
It could be possible that a flour, when brought to the same protein level, may bake better than another flour which was rated better on an as is basis.

It was found in this study that by the use of air separation, controlling flour protein could be accomplished successfully. Using data collected in this study a graph (Fig. 37) was plotted as a predicted flour recovery chart. Twelve per

FIG. 37

PREDICTION CHART

AMOUNT OF FLOUR THAT CAN BE SHIFTED TO 12% PROTEIN FROM 100LBS OF WHEAT



cent protein was considered the most desirable protein level of flour for evaluation purposes of Hard Red Winter Wheat. Working on a 70 per cent flour extraction basis from wheat, calculations were made to find the amount of flour, at 12% protein, that could be obtained after a protein shifting procedure starting with different initial flour protein levels. This should be a useful tool to predict the amount of flour required for fractionation purposes to make flour for collaboration studies.

SUGGESTIONS FOR FUTURE WORK

Air separation procedure is a practical and useful tool for controlling flour protein level. A great deal of work needs to be done on the effects due to different methods of protein control.

The amino acid distribution in the air classified fractions should be studied further.

Zeleny Sedimentation values of high and low fraction are difficult to assay. The reason for this problem could give a better understanding of the limits of the Zeleny Sedimentation test.

The cake baking properties of the starchy fractions from Hard Red Winter Wheat flour should be investigated. Fractions from Hard Red Winter Wheats could be used more for making cake flours.

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Last but not least, I express my grateful appreciation to all the members of the department who most willingly gave all assistance and advice during the course of my work.

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CONTROLLING FLOUR PROTEIN LEVEL BY USE OF AIR SEPARATION

by

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The purpose of this study was to develop a procedure by which wheat flour protein level could be controlled by the use of air separation.

Wheat flour is a heterogenous material made up of many different constituents and properties. Air classification makes it possible to concentrate some of the constituents and thus make flours with different properties. Protein content was one of the primary measurements used in this study.

Straight grade flour from two hard red winter wheats of different protein content were air classified into five sub-sieve size fractions to give two high protein fractions, two starchy or low protein fractions and a chunk fraction of similar protein level as the original flour. Blends were made from fractions of the two wheat flours to four protein levels, 9.9, 10.7, 11.6, and 13 per cent. The blends were tested for their physical dough and bread baking properties. In blending, efforts were made to keep all properties as close to the parent flour as possible while regulating the protein content. The two starchy fractions were used for shifting the protein level in all but one of the blends.

A statistical analysis indicated a highly significant negative correlation between maltose and particle size. When protein content was held constant, a highly significant correlation between Zeleny sedimentation and particle size was observed. With particle size held constant there was no correlation between Zeleny sedimentation and protein content.

A highly significant correlation between protein content and loaf volume was also observed.

The results of the investigations indicate that after air classification, fractions can be recombined to provide flours of a uniform, desirable protein content. The blends obtained were very similar in their analytical and physical dough properties to the parent flours. The bread baking properties were related to the protein content. There was an improvement of bread baking total score with increase in protein content.

On adjusting protein level, by the use of air separation, to a common level a better comparison of the two flours was possible. Though the Triumph flour baked better, the Commercial Mix flour compared more favorably with the Triumph at common protein levels than in their original form.