AIR CLASSIFICATION OF WHEAT FLOURS

by

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INTRODUCTION

Fine grinding and air classification were introduced to the milling industry about eleven years ago. These make possible the production of flour of more uniform properties from wheats of abnormal high protein content. Flour produced by air classification can increase industrial uses of cereal grains such as wheat, corn and sorghum. Fractions can be produced from cereal flours that should be more useful for food, feed and fermentation industries. Hard red winter wheats, which are the most plentiful, offer immense quantities of raw material for conversion to new and improved commercial products.

The application of fertilizer, irrigation and the amount of rainfall influence the protein content of wheat. Both yield of grain and protein content can be increased by timely application of adequate amounts of nitrogenous fertilizers (4,63). There are several methods used to regulate the protein content of flour in the milling process. Flour streams vary considerably in protein content. Middling flour streams usually have a relatively low protein content while the break and tail mill streams are relatively high. The flour streams may range from 11 to 16 percent protein and therefore, the appropriate selection of flour streams makes it possible to control the protein content of flour within limits.

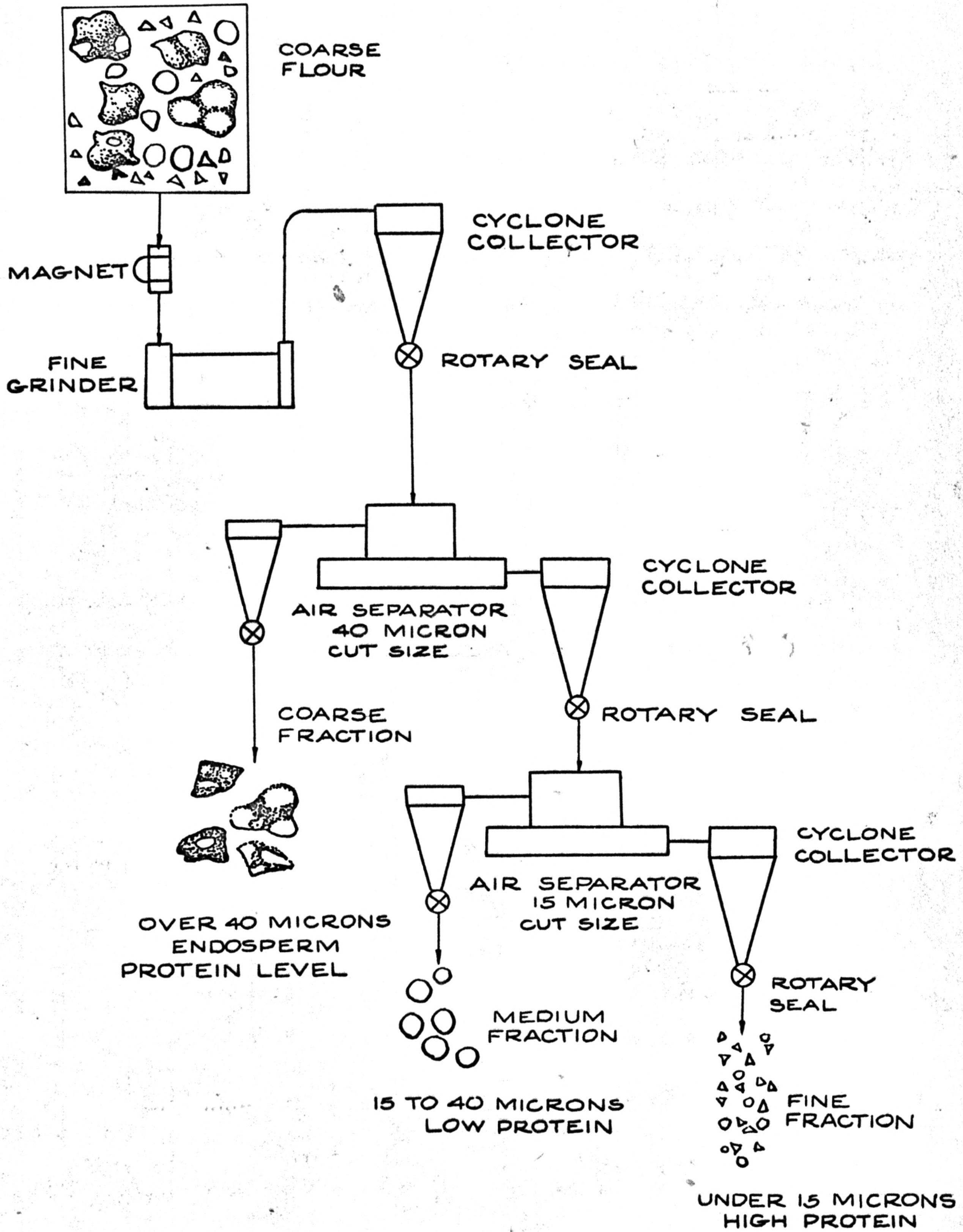
The size and structure of flour particles suggest that if a size separation can be made at a certain point, the very small starch granules and the broken portions of the protein matrix will be found in the fine fraction, whereas the agglomerated material and the larger free starch granules will be found in the coarse fraction. This makes it possible to concentrate the protein. Elias et al., (15) stated a machine used for this purpose is the centrifugal air classifier in which air-drag forces can be counter balanced by high centrifugal fields to give terminal velocity separations at much smaller sizes than was hitherto possible.

Griffin et al., (72) reported regrinding the flour increased the yield of fine fractions; reduced the yield of coarse residue, and increased the range of protein content in the fractions. Griffin et al., (72) also reported that extreme variation existed in response to air classification of flour from the same variety grown in different areas, or from the same varieties grown in the same area, or grown during different seasons.

For a fair quality evaluation, a minimum number of variables are desirable. Protein content is the main variable which affects the bread baking evaluation of a wheat flour. Therefore, it would be desirable to obtain flour of the same protein content. This should make possible a good evaluation of protein quality independent of protein content. Controlling protein level is of interest to many cereal research scientists.

The aim of this study was to investigate a procedure by which the protein level of wheat flour can be controlled by the use of air classification. A simplified protein shift process diagram by which this may be done is shown in Fig. 1. This study deals with the composition and properties of wheat flour, such as, protein, ash, particle size and maltose.

Fig. 1. SIMPLIFIED PROTEIN SHIFT PROCESS DIAGRAM



REVIEW OF LITERATURE

Several researchers (54,81) have revealed that the center portion of the wheat kernel contains a flour having the lowest ash and protein content. As endosperm portions radiate like circular layers out toward the bran coat, they increase in their ash and protein content. The fact was also revealed that these portions, depending upon their location inside the wheat kernel, have different inherent chemical, physical, and baking properties (66,82). Within the endosperm itself there is thought to be a differential distribution of ash and protein such as to account for differences in the composition of the individual mill stream flours (54). Cobb (11) has demonstrated a relatively sharp gradient in the protein content of endosperm layers from center to the bran coat. Estimates by several technologists on the ash content of the pure endosperm as a whole are as follows: Simon (69) 0.32, Kent-Jones (39) 0.30, and Swanson (75) about 0.36 percent. Bailey (6) found that the percentage of gluten decreased progressively from the outer to the central part of the endosperm.

Schlehuber et al., (64) reported that both yield and protein content can be increased by timely application of adequate amounts of nitrogenous fertilizers (13,70,19,20,18). Abbott et al., (64) have shown that the sedimentation values tended to be correlated with the nitrogen content. Larger loaf volumes were produced from the higher rates of nitrogen application, regardless of variety of wheat. Longer Farinograph mix times were obtained with the higher rates of nitrogen application. Baking quality scores increased by higher rates of nitrogen application, regardless of variety. Curtis (12) stated that the concentration of soil nitrogen and moisture determined the protein content and grain yield. When neither the nitrogen nor moisture were limited, both the protein content and the yield were high, while if both the nitrate and moisture were limited, the protein content and yield were correspondingly low. When the nitrogen level was high and the moisture was low, the protein content was high but the yield was low. If the moisture was high and the nitrate was low, the yield was high, but the protein content was low. Eck (13) stated that the nitrogen in excess of that required for grain yield increases was used to build more protein in the grain. El Gindy et al., (14) stated that the application of nitrogen in some cases increased the percent protein in wheat and flour. Gericke (24,25) and the others (36) showed also that the amount of available nitrogen in the soil influenced the protein content of wheat.

The protein content range of different groups of wheat that were evaluated for bread baking properties clearly indicate that a wide variation existed during the last four years. Data are listed in Table 1. The 4 year average protein content for the spring wheat area was 14.68, while that for the hard red winter wheat area was 12.76. In both areas, the wide variation in protein content caused a considerable difficulty in evaluating bread baking quality. The samples from the Hard Red winter area exhibited less variation in the protein content, than the spring wheat area.

Barmore et al., (8,7) have reported that wheat flour is

Table 1. The wheat protein content* range of different groups (46-53 Incls.).

	Hard Red Spring Wheat Area				Hard Red Winter Wheat Area			
Year	1960	1961	1962	1963	1960	1961	1962	1963
Low Prot.	10.4	12.3	11.7	13.1	11.2	10.4	10.68	12.10
High Prot.	17.1	17.2	15.8	17.0	15.4	13.5	15.72	13.62
Aver. Prot.	14.4	14.8	14.1	15.5	12.6	12.6	13.0	12.9
No. of samples	42	23	18	20	19	16	16	13
		Hard Red Winter Wheat						
Low Prot.		10.15	10.5	9.6				
High Prot.		16.9	16.8	14.6				
Aver. Prot.		14.14	12.66	11.47				
No. of samples		28	17	21				

* Expressed on 14% moisture basis.

nonhomogenous with respect to particle size and therefore may be air-classified to provide distinct fraction. The air-classification procedure causes dramatic chemical differences as well as notably different average particle sizes. These differences imparted distinct dough handling and baking properties to each fraction. The utility of these fractions is governed by their physical characteristics and chemical composition.

As early as 1919 Leclerc and co-workers (41) separated a flour into coarse, intermediate, and fine fractions by sieving and found that the intermediate fraction produced the best bread. The studies by Wichser, et al., 1947 to 1950 (67), led to the first comprehensive reports dealing with the separation of bread flour into particle-size ranges and accurate measurement of the particle size. The resulting fractions were chemically analyzed and baked. The best bread was produced from the fraction having particles in the 38 to 61 - micron range. Protein content was the dominant factor influencing the properties of each fraction. Peplinski et al., (56) reported the two finest fractions were higher in ash and maltose than the remaining coarser fractions.

Finney and Barmore (21) found great differentiations in loaf volume due to differences in protein content. Higher protein content flour was associated with greater loaf volume.

Auer (5) and others (16,17,15,71) reported that regrinding the flour before air-classification increased the yield of "fine" fractions, reduced the yield of coarse fractions, and therefore increased the range of protein content in the fractions. Pfeifer, et al., (59) reported that in each classification ash constituents concentrated in the finer fractions and tended to follow variation in the protein content. Below 38 microns was referred to as the sub-sieve size range (34). Pfeifer et al., (60) also pointed out that regrinding the flour before air-classification increased the range of composition of the fractions. Pfeifer et al., (73,58) stated: "Regrinding increased the ash content of the fine fractions and usually lowered the 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."

Peplinski et al., (57) made studies on separation of hard and soft wheat flours. They concluded that for each variety the eight-part fractionation yielded a wider range in protein content of fractions than did the four-part fractionation. This difference would be expected, since the eight-part fractionation included more extensive regrinding. In the four-part fractionation, about one-half of the flour was separated first as coarse residue, and then only the remaining fine portion was reground. The coarse residue from the four-part classification was an important fraction, because it was fortified with the high-protein fraction to a protein level preferred for bread baking.

Wichser (83) reported that high protein fractions improved bread baking quality while high starch fractions were specifically useful for pastries. Harris (32) separated six fractions by air-classification from one hard red spring wheat flour. The best loaves occurred with the intermediate particle size fraction while the smallest particle size fraction produced the poorest bread. Kress (40) and others (38,45,68) have recognized that flour particles vary in size and differed in chemical and physical properties as well as that baking quality.

Elias et al., (15) found: that high-protein fractions obtained from soft wheat flour were suitable for breadmaking, but could also serve as a fortifying agent. The low-protein or "middle cut" fraction protein fulfilled the requirements for specialty cake flours. The medium protein or "coarse fraction" had a specialized value for biscuit manufacture.

Harris and the others (32,33,1) stated that the low protein fractions from air classified hard winter wheat make cake flours which were considered even better than those obtained from soft wheat.

Alsberg, Griffing (2) and others (76,37,62) reported that during the milling process a portion of the starch of the endosperm of the wheat became damaged. The mechanical damage occurred while the endosperm as a result of shearing action or crushing effect on large particles. The shearing action was designated to as the surface factor while the crushing effect was designated as the "internal factor." Under the microscope the mechanically damaged starch granules were found different than the undamaged starch granules. The damaged starch granules readily stained with certain dyes. Ponte et al., (61) reported that maltose value and water absorption increased as the extent of starch damage increased; however, the loaf volume decreased.

A hard winter wheat, 90 percent patent flour was air-classified into six particle size ranges by Sullivan et al., (74). They found both the ash and protein content varied with the particle size. For a very low micron size, the ash content was roughly double that of the original flour. Maltose value decreased as particle size increased to approximately 70 microns. Wichser et al., (84) also reported that flour particles vary in size and exhibit marked differences in chemical and physical characteristics. Particle size of flour particle may be determined by several means.

Nenninger (55) determined particle size by air elutriation, microscopic examination and sieving.

Barrett (8) and others (30,29) report that the ash content of the fractions varies, being generally higher in the finer fraction; i.e., as protein content increased the ash content also increased. Irani and Fong (36) stated that the particle size distribution of flour, measured microscopically, or by gravitational sedimentation, centrifugal sedimentation, and sieving, all gave mean diameters and distribution curves which agreed with one another within experimental error. Whitby (79,80) and Heywood (35) discussed the mechanics of fine sieving and concluded that sieving can be divided into two different steps. During the first step, particles with a size much smaller than the sieve opening pass through. During the second and relatively slower step, particles whose size is close to that of the opening are sieved through.

In other studies relating to flour particle size, Wichser et al., (84,83,85,86) stated "flour particles have a 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.

Carman (10) and others (27,28) reported the Fisher sub-sieve sizer indicated most likely some measure of specific surface; with decreasing Fisher value the specific surface increased. Because of the higher specific surface of the small particles, the moisture content was lower in the smaller particle size ranges. Schaefer (65) reported that sedimentation values decrease with increasing flour ash content. Grosh et al., (31) reported both fractured starch and fine gluten particles increase flour absorption. Gracza stated (30,29) that dough development times increase with increasing protein content. Grosh et al., (31) reported dough properties of the coarse separations were similar to those of the original flours. Grosh et al., (31) also stated that Farinograms revealed that the high protein fractions had the highest absorption and unusually long mixing time, while the low protein fractions had the shortest mixing time and lowest absorption.

Merritt and Geddes (44) reported results of blending experiments showing complementary effects of one flour on another.

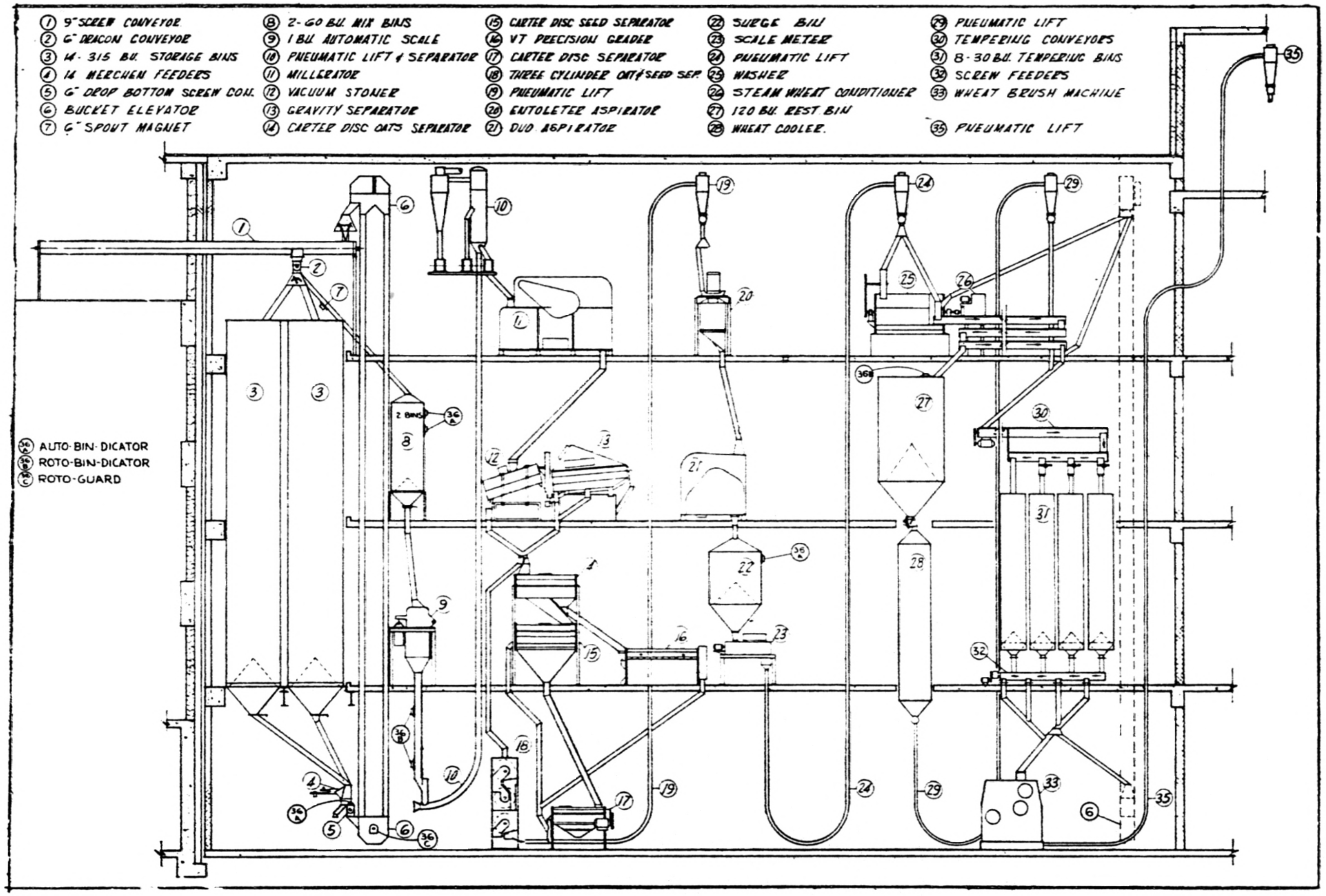
MATERIALS AND METHODS

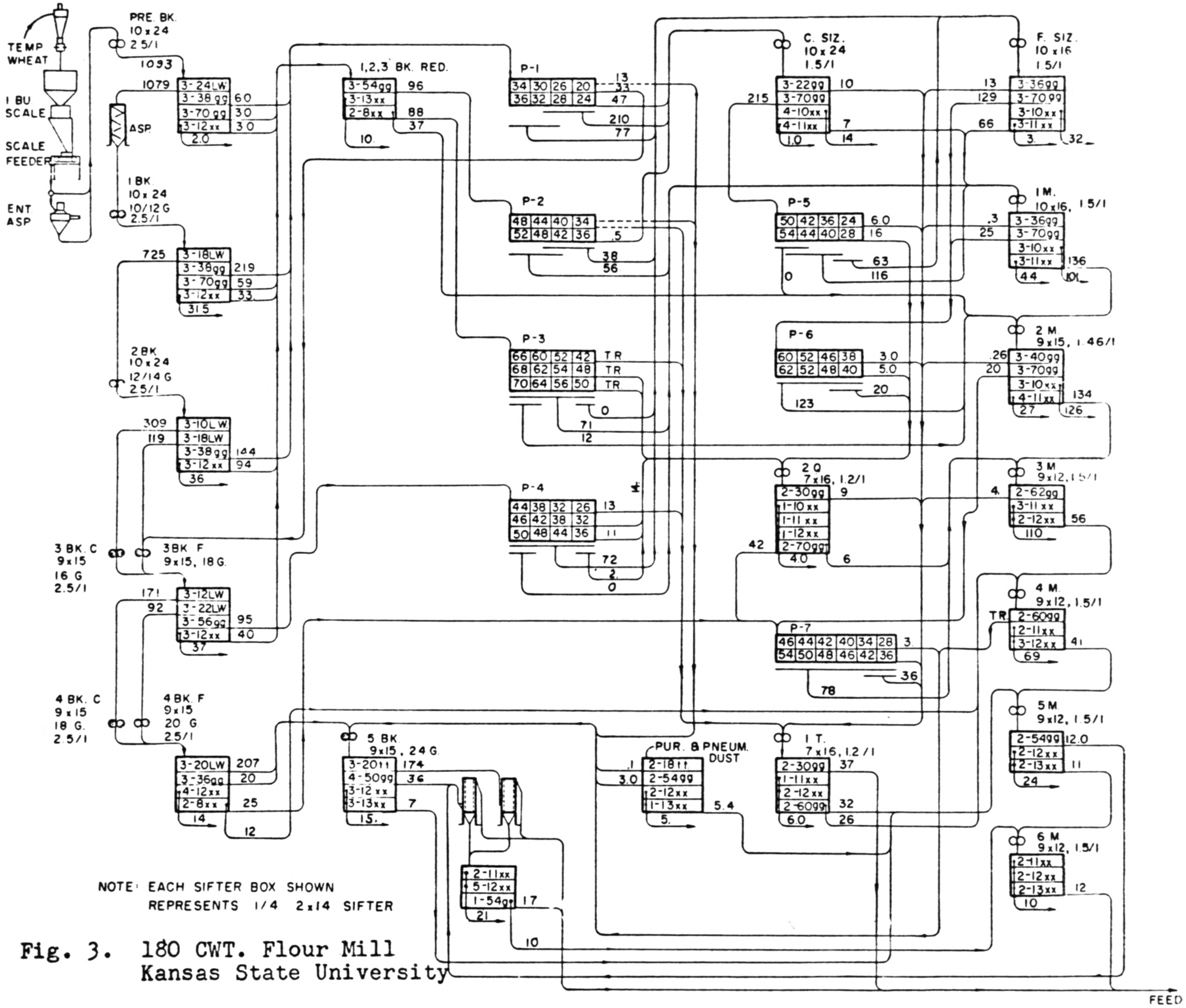
Cleaning, Tempering, and Milling

The wheat varieties used in this study for protein control were Triumph and Kaw, grown with and without fertilizer. These four samples were cleaned in the KSU pilot mill cleaning house (Fig. 2). 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 percent moisture and allowed to rest for twenty hours before milling. The wheat was milled into flour on the KSU pilot flour mill. The flour mill consisted of a five break and ten reduction system (Fig. 3).

Fig. 2 **Schematic Flow of Kansas State's Grain Cleaning Facilities**





NOTE: EACH SIFTER BOX SHOWN REPRESENTS 1/4 2x14 SIFTER

Fig. 3. 180 CWT. Flour Mill
Kansas State University

Air-Classification

The four straight grade flours produced on the KSU pilot mill were used for air classification. The data representing protein content and extraction rate for the straight grade flours are listed in Table 2. The parent flour was fractionated 40 days after milling. The flour received no additional grinding. The parent flour was fractionated in a Pillsbury laboratory-model turbo-air classifier (22,42,43). This fractionation produced five fractions from the parent flour. The finest fraction of highest protein content was removed first. The remaining coarse material was passed through the classifier again. This procedure was repeated until five fractions were obtained. Fractionation by air-classification made simultaneous use of size, shape, and density of the particles.

Table 2. Protein and Extraction data of four straight grade flours.

Wheat	Flour Protein Percent*	Flour Extraction Percent
Triumph without fertilizer	10.03	76.33
Triumph with fertilizer	12.0	75.03
Kaw without fertilizer	10.6	74.47
Kaw with fertilizer	12.08	75.27

* Reported on 14 percent M. B.

Each of the four samples was passed through the classifier in the same way. The classifier settings for the four stage fractionation which produced five fractions were as follows:

	R.P.M.	Deck	Curvature of classified Blades	Louvre Curtain	Feed Rate
1st stage	5800	6	Forward	10°	100lbs/hr
2nd stage	5800	6	Backward	10°	100lbs/hr
3rd stage	3600	2	Backward	10°	50lbs/hr
4th stage	3600	2	Backward	35°	25lbs/hr

The fraction cut-point was made by adjustment of the classifier speed, angle of louver curtain, direction of classifier blade curvature, effective depth of classifier chamber (decks), and feed rate. Each stage or "cut" produced a fine fraction which was collected, and a coarse fraction which was further classified into two fractions by readjusting the classifier for a coarser cut. This procedure was repeated until four fine fractions and one coarse fraction were obtained. The five fractions thus obtained from the parent flour (A) were separated and designated as below:

B) Primary high protein, the first fine fraction.

C) Secondary high protein, the second fine fraction.

D) Small starch, the third fine fraction.

E) Large starch, the fourth fraction.

EE) Chunks, the remaining coarse fraction.

Figure 4 shows a cross section of the type separator used. Flour was fed into the top of the machine onto a rotating plate which deagglomerated and imparted centrifugal force to each particle. The particles were thrown outward through a stream of air which retained the fine particles by a drag force (centripetal force), but which could not overcome the centrifugal force of the

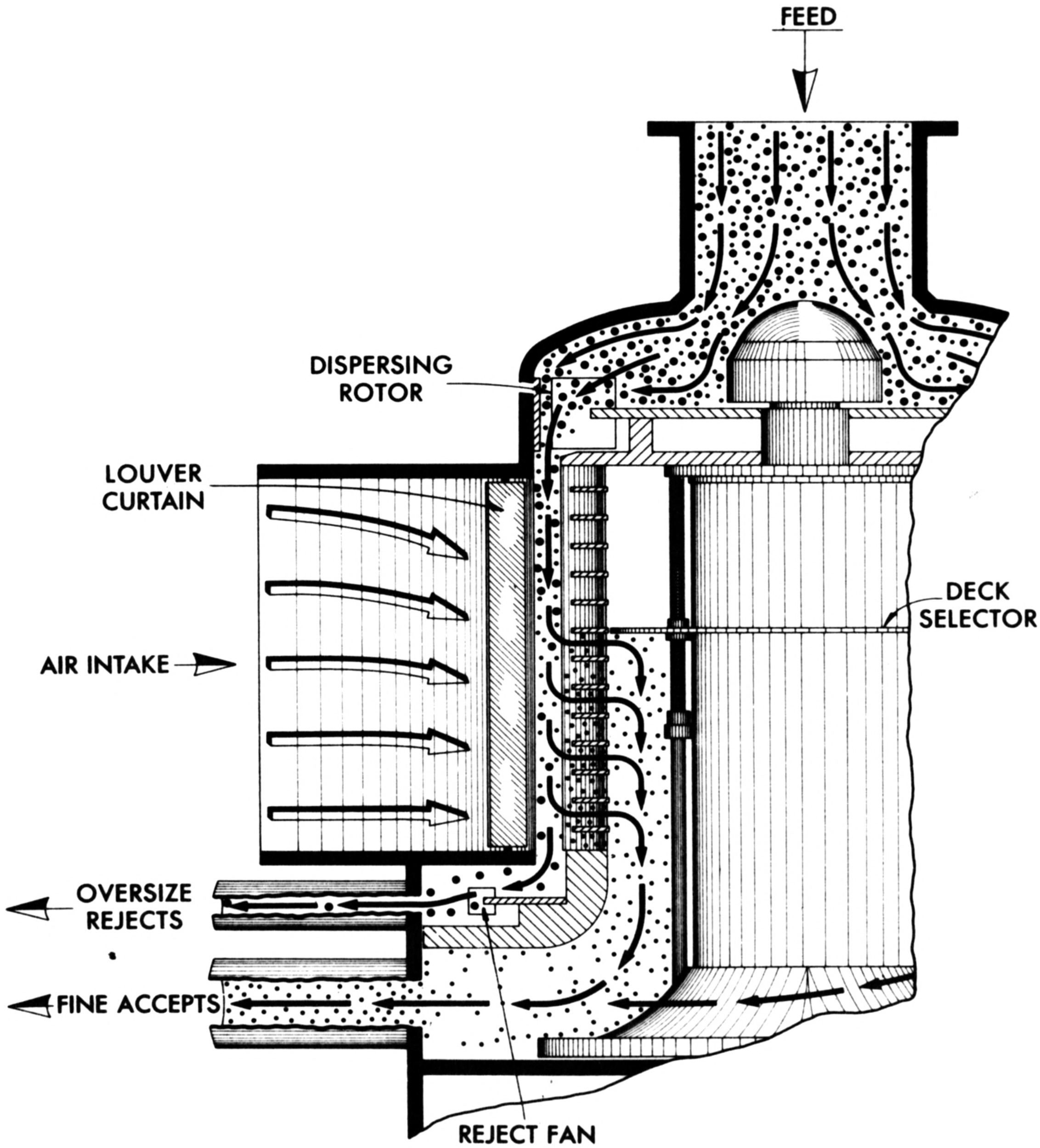


Fig. 4. A schematic diagram of how air classification can be used to separate coarse and fine particles.

larger particles. The flour was thereby separated into a fine and coarse fractions.

Blending

The air-classified fractions from the four straight grade flours were blended to bring the protein content to a theoretical level, 11.3 percent. Considerable effort was made during the protein blending process to keep all properties of blends as close to the parent flour as possible. In the blending process, there were a number of combinations that could be utilized for raising or lowering the protein content level of the parent flour. These methods were:

1) Blending of certain air-separated fractions to provide flour of given protein content.
2) Addition of certain air separated fractions to the parent flour.
3) Addition of certain air separated fractions to certain flour mill streams.

Method 1 was used to raise the flour protein to the desired level of 11.3 percent. Method 2 was used to lower the protein to 11.3 percent.

Analytical Determinations

The parent flour and each fraction from air classification, and blends were analyzed for protein, moisture, and ash as outlined in Cereal Labaratory Methods (3). Particle size measurements were made by the Whitby method (77,78) which were based on the settling velocity of particles in the gravitational field. They also tested for average particle size (Fisher), Agtron color and Zeleny sedimentation. Fisher average particle size was determined as outlined by the Fisher Scientific Co. (9,28,27). The Fisher sub-sieve-sizer (27) which employs the principle of permeability of porous beds was first used by Carman (10) and later by Gooden and Smith (28). Agtron color was determined as outlined by Gillis (26). Zeleny sedimentation value was determined in Cereal Lab Methods (3). The samples were also tested for maltose and starch damage. Farinographs were made as outlined in Cereal Labaratory Methods (3). Parent flours and blends were subjected to bread baking tests as outlined in Cereal Labaratory Methods (3).

RESULTS AND DISCUSSIONS

The fine fraction produced higher yield with backward direction than with forward direction of rotor blade curvature. As the rotor speed increased, the fineness of the particle decreased. The flour protein was concentrated in the fine fractions of stage 1 and 2 and the starch in the fine fractions of stage 3 and 4. Significant increases or decreases in protein content were accompanied by similar changes in ash content.

Protein content range of the 5 air-classified fractions for 4 flour samples were as follows:

	Protein (%)
Triumph without fertilizer	5.64% - 27.6%
Triumph with fertilizer	6.78% - 29.3%
Kaw without fertilizer	6.95% - 28.2%
Kaw with fertilizer	7.62% - 26.0%

The very finest flour particles, collected in the filter bag, were very high in protein but small in quantity. The protein, ash, and moisture of this material were as follows:

	Protein (%) 14% M.B.	Ash (%) 14% M.B.	Moisture (%)
Triumph without fertilizer	47.5	.962	6.1
Triumph with fertilizer	49.8	1.01	6.3
Kaw without fertilizer	44.7	1.1	6.1
Kaw with fertilizer	45.3	1.01	6.3

Analytical Characteristics of the Fine Air-Classified Fractions

The analytical results for fractions of Triumph wheat flour without fertilizer are shown in Fig. 5, and those for Triumph wheat flour with fertilizer are shown in Fig. 6. The analytical results for fractions of Kaw wheat flour without fertilizer are shown in Fig. 7, and those with fertilizer are shown in Fig. 8.

The histograms of the protein of the different fractions are shown in Fig. 9, ash values in Fig. 10, Zeleny sedimentation, particle size, and Agtron color in Fig. 11, 12, and 13, respectively. Maltose, starch damage and peak mixing time are shown in Fig. 14, 15, and 16, respectively. The Whitby sedimentation curves for the fractions were plotted in Fig. 17, 18, 19, and 20, for each sample, respectively.

The histograms in Fig. 9 shows that the protein for all flour

Fig. 5.
LAB SIZE CLASSIFIER
TRIUMPH WHEAT FLOUR WITHOUT
FERTILIZER
5 S.S.S. FRACTIONS

A

Prot.	10.03%
Ash	0.38%
Moist.	11.8%
Fisher	19.7
Zeleny	38 c.c.
Maltose	170
Peaktime	5.0 mins.

5800 R.P.M. 6DF.
10°L.C.-100#/hr.

B

3.8%

Prot.	27.6%
Ash	.603%
Moist.	7.4%
Fisher	2.9
Zeleny	77.0 c.c.
Maltose	350
Peaktime	23.25 mins.

BB

96.2%

Prot.	9.6%
Ash	.37%
Moist.	9.4%
Fisher	18.25
Zeleny	38 c.c.

5800 R.P.M. 6DB
10°L.C.-100#/hr

C

11.0%

Prot.	17.3%
Ash	.528%
Moist.	7.1%
Fisher	4.8
Zeleny	77.0 c.c.
Maltose	396
Peaktime	17.0 mins.

CC

85.2%

Prot.	8.57%
Ash	.352%
Moist.	9.7%
Fisher	22.0
Zeleny	34.0 c.c.

3600 R.P.M. 2DB
10°L.C.-50#/hr

D

15.3%

Prot.	7.0%
Ash	.398%
Moist.	9.2%
Fisher	10.7
Zeleny	70.0 c.c.
Maltose	342.0
Peaktime	2.0 mins.

DD

69.9%

Prot.	9.92%
Ash	.332%
Moist.	9.1%
Fisher	24.0
Zeleny	36.0 c.c.

3600 R.P.M. 2DB
35°L.C.-25#/hr

E

14.8%

Prot.	5.64%
Ash	.375%
Moist.	8.4%
Fisher	15.5
Zeleny	65.0c.c
Maltose	250
Peaktime	1.5 mins.

EE

55.1%

Prot.	10.02%
Ash	.337%
Moist.	10.6%
Fisher	27.6
Zeleny	40.0c.c
Maltose	110
Peaktime	4.25 mins.

Fig. 6.
LAB SIZE CLASSIFIER
TRIUMPH WHEAT FLOUR WITH
FERTILIZER
5 S.S.S. FRACTIONS

A
Prot. 12.0%
Ash .37%
Moist. 11.7%
Fisher 18.0
Zeleny 54.0 c.c.
Maltose 134
Peaktime 6.5 mins.

5800 R.P.M. 6DF
10°L.C.-100#/hr

3.5%
Prot. 29.3%
Ash .549%
Moist. 7.5%
Fisher 2.95
Zeleny 76.0 c.c.
Maltose 325
Peaktime
B 24.0 mins.

96.5%
Prot. 11.8%
Ash .339%
Moist. 11.2%
Fisher 17.1
Zeleny 50.0 c.c.
BB

5800 R.P.M. 6DB
10°L.C.-100#/hr

11.4%
Prot. 18.7%
Ash .476%
Moist. 7.9%
Fisher 4.8
Zeleny 76.0 c.c.
Maltose 304
Peaktime
C 17.0 mins.

85.1%
Prot. 10.6%
Ash .336%
Moist. 10.2%
Fisher 20.05
Zeleny 43.0 c.c.
CC

3600 R.P.M. 2DB
10°L.C.-50#/hr

15.6%
Prot. 8.64%
Ash .382%
Moist. 14.4%
Fisher 10.6
Zeleny 46.0 c.c.
Maltose 242.0
Peaktime
D 2.5 mins.

69.5%
Prot. 11.9%
Ash .342%
Moist. 14.6%
Fisher 22.6
Zeleny 46.0 c.c.
DD

3600 R.P.M. 2DB
35°L.C.-25#/hr

15.2%
Prot. 6.78%
Ash .349%
Moist. 8.7%
Fisher 14.2
Zeleny 28.0c.c
Maltose 234
Peaktime 1.75 mins.
E

54.3%
Prot. 12.45%
Ash .323%
Moist. 9.4%
Fisher 26.2
Zeleny 59.0c.c
Maltose 102
Peaktime 5.25 mins.
EE

Fig. 7.
LAB SIZE CLASSIFIER
KAW WHEAT FLOUR WITHOUT
FERTILIZER
5 S.S.S. FRACTIONS

A
Prot. 10.6%
Ash .371%
Moist. 11.8%
Fisher 22.0
Zeleny 41.0 c.c.
Maltose 170
Peaktime 8.0 mins.

5800 R.P.M. 6DF
10°L.C.-100#/hr

B
3.6%
Prot. 28.2%
Ash .636%
Moist. 6.7%
Fisher 2.95
Zeleny 77.0 c.c.
Maltose 403
Peaktime 46.5 mins.

BB
96.4%
Prot. 10.5%
Ash .352%
Moist. 9.6%
Fisher 18.9
Zeleny 41.0 c.c.

5800 R.P.M. 6DB
10°L.C.-100#/hr

C
10.5%
Prot. 16.6%
Ash .52%
Moist. 7.2%
Fisher 4.9
Zeleny 76.0 c.c.
Maltose 393
Peaktime 17.0 mins.

CC
85.9%
Prot. 10.14%
Ash .35%
Moist. 9.2%
Fisher 22.0
Zeleny 39.0 c.c.

3600 R.P.M. 2DB
10°L.C.-50#/hr

D
15.1%
Prot. 7.55%
Ash .388%
Moist. 8.9%
Fisher 10.75
Zeleny 67.0 c.c.
Maltose 298
Peaktime 1.5 mins.

DD
70.8%
Prot. 10.46%
Ash .339%
Moist. 8.8%
Fisher 24.2
Zeleny 40.0 c.c.

3600 R.P.M. 2DB
35°L.C.-25#/hr

E
12.8%
Prot. 6.95%
Ash .386%
Moist. 8.4%
Fisher 14.0
Zeleny 33.0c.c
Maltose 230
Peaktime 1.5 mins.

EE
58.0%
Prot. 11.16%
Ash .321%
Moist. 9.0%
Fisher 28.2
Zeleny 46.0c.c
Maltose 118
Peaktime 9.5 mins.

Fig. 8.
LAB SIZE CLASSIFIER
KAW WHEAT FLOUR WITH
FERTILIZER
5 S.S.S. FRACTIONS

Prot.	12.08%
Ash	.37%
Moist.	11.6%
Fisher	23.0
Zeleny	48.0 c.c.
Maltose	166
Peaktime	10.0 mins.

A.

5800 R.P.M. 6DF
10°L.C.-100#/hr

3.2%

Prot.	26.0%
Ash	.657%
Moist.	8.3%
Fisher	2.9
Zeleny	76.0 c.c.
Maltose	419
Peaktime	49.0 mins.

B

96.8%

Prot.	11.4%
Ash	.355%
Moist.	10.2%
Fisher	20.0
Zeleny	49.0 c.c.

BB

5800 R.P.M. 6DB
10°L.C.-100#/hr

10.1%

Prot.	15.95%
Ash	.556%
Moist.	7.2%
Fisher	5.05
Zeleny	76.0 c.c.
Maltose	467
Peaktime	19.0 mins

C

86.7%

Prot.	11.1%
Ash	.342%
Moist.	9.3%
Fisher	23.7
Zeleny	47.0 c.c.

CC

3600 R.P.M. 2DB
10°L.C.-50#/hr

13.9%

Prot.	8.1%
Ash	.386%
Moist.	8.6%
Fisher	10.3
Zeleny	70.0 c.c.
Maltose	346
Peaktime	1.5 mins.

D

72.8%

Prot.	11.5%
Ash	.341%
Moist.	9.2%
Fisher	26.2
Zeleny	49.0 c.c.

DD

3600 R.P.M. 2DB
35°L.C.-25#/hr

11.8%

Prot.	7.62%
Ash	.405%
Moist.	8.5%
Fisher	13.5
Zeleny	42.0c.c
Maltose	277
Peaktime	1.75 mins.

E

61.0%

Prot.	11.66%
Ash	.332%
Moist	9.2%
Fisher	29.2
Zeleny	57.0c.c
Maltose	106
Peaktime	10.75 mins.

EE

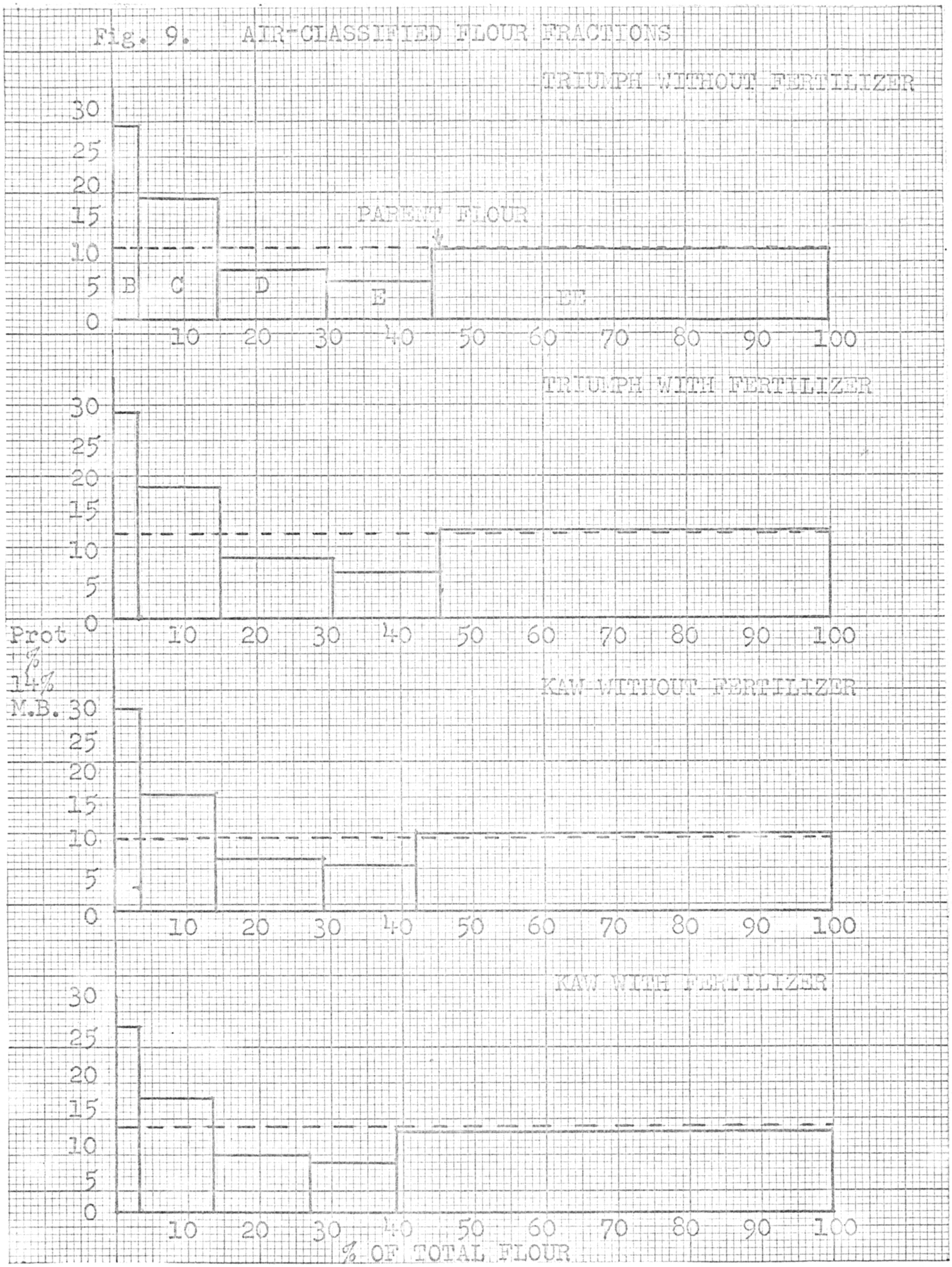
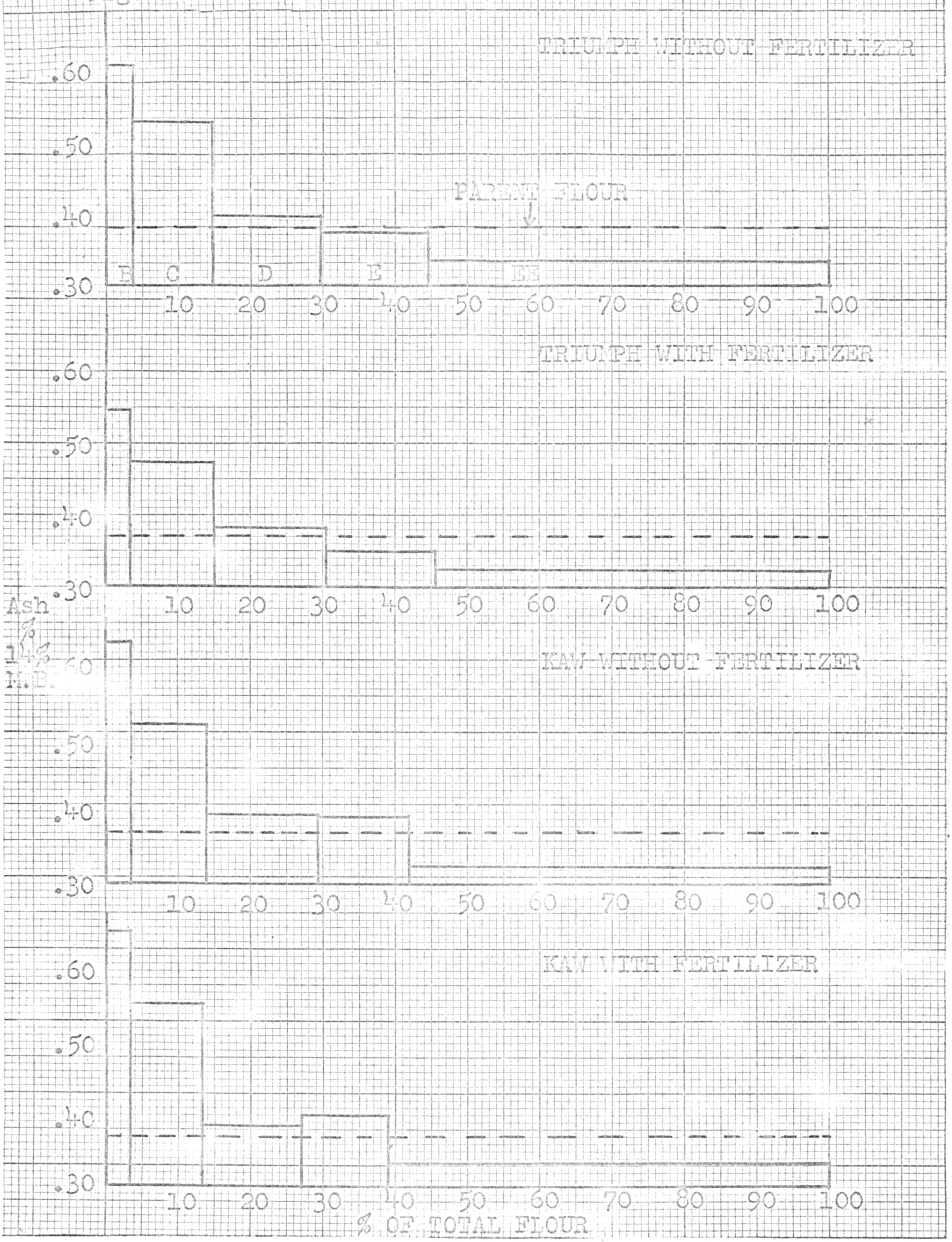


Fig. 9. AIR-CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
PARENT FLOUR
B
C
D
E
EE
TRIUMPH WITH FERTILIZER
Prot % 14% M.B.
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
% OF TOTAL FLOUR

Fig. 10. AIR CLASSIFIED FLOUR FRACTIONS



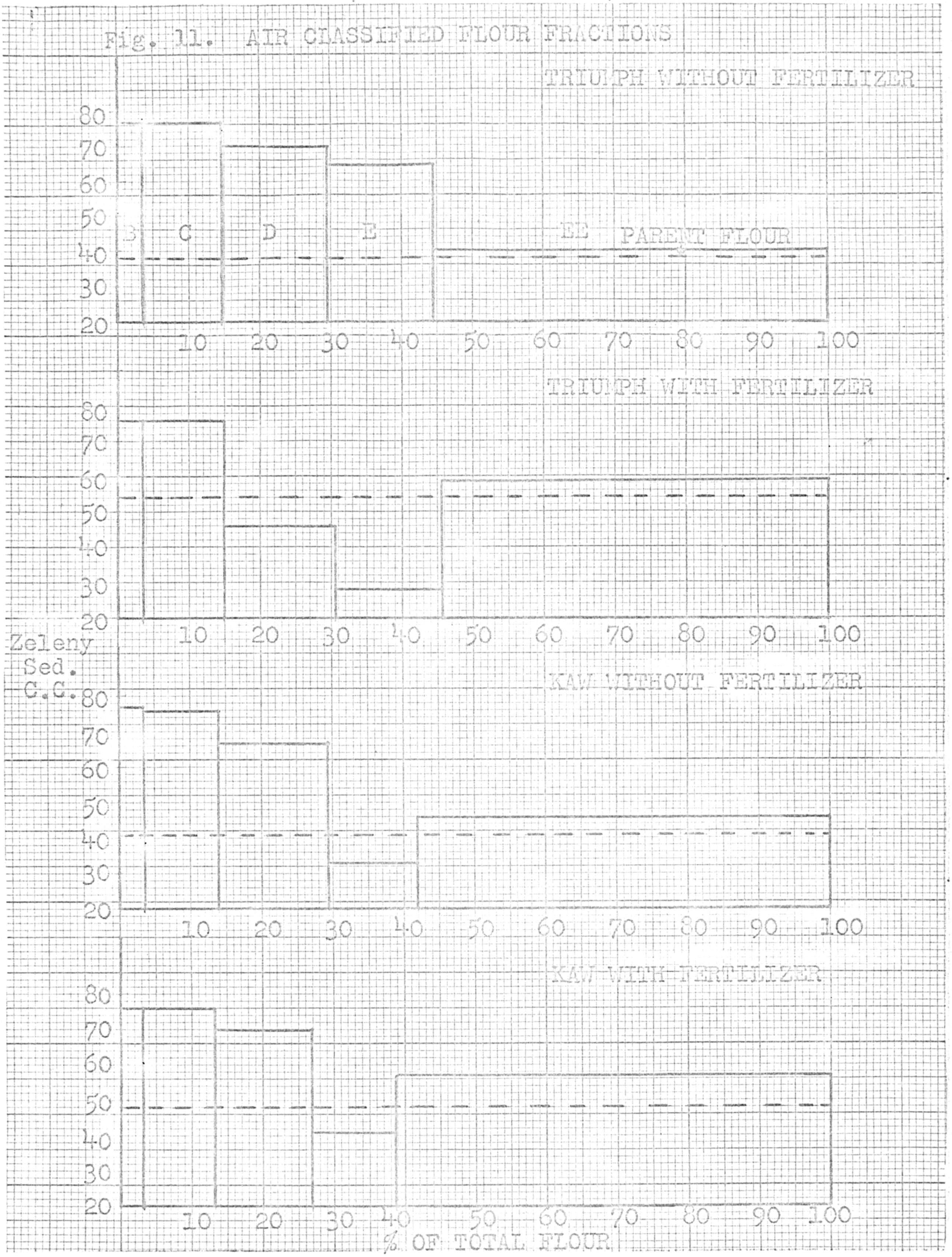


Fig. 11. AIR CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
B
C
D
E
EE
PARENT FLOUR
TRIUMPH WITH FERTILIZER
Zeleny Sed. C.C.
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90
100
% OF TOTAL FLOUR

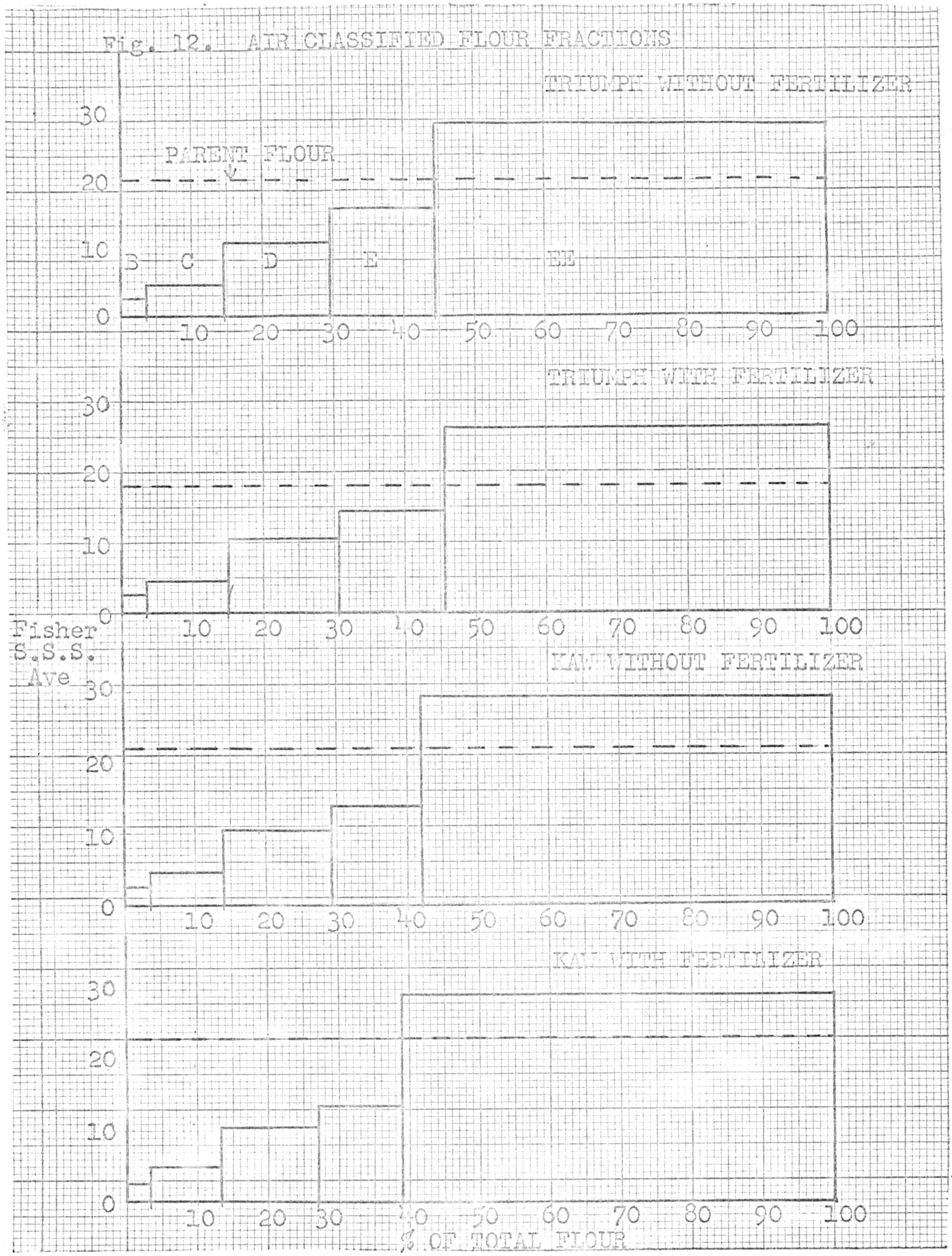


Fig. 12. AIR CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
PARENT FLOUR
B
C
D
E
EE
TRIUMPH WITH FERTILIZER
Fisher S.S.S. Ave
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
0
10
20
30
10 20 30 40 50 60 70 80 90 100
% OF TOTAL FLOUR

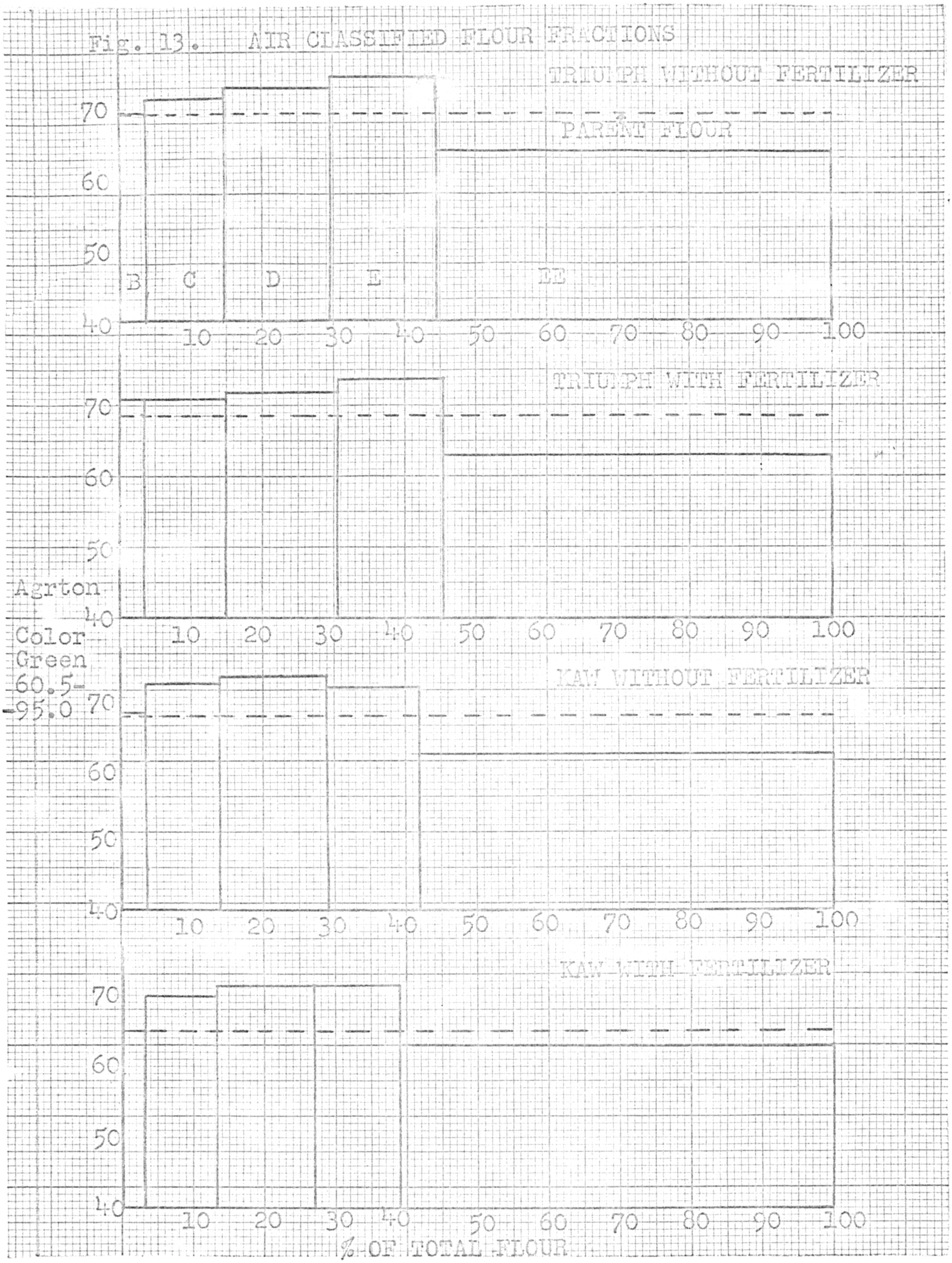


Fig. 13. AIR CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
PARENT FLOUR
B C D E DE
TRIUMPH WITH FERTILIZER
Agrton Color Green 60.5-95.0
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
70
60
50
40
10 20 30 40 50 60 70 80 90 100
% OF TOTAL FLOUR

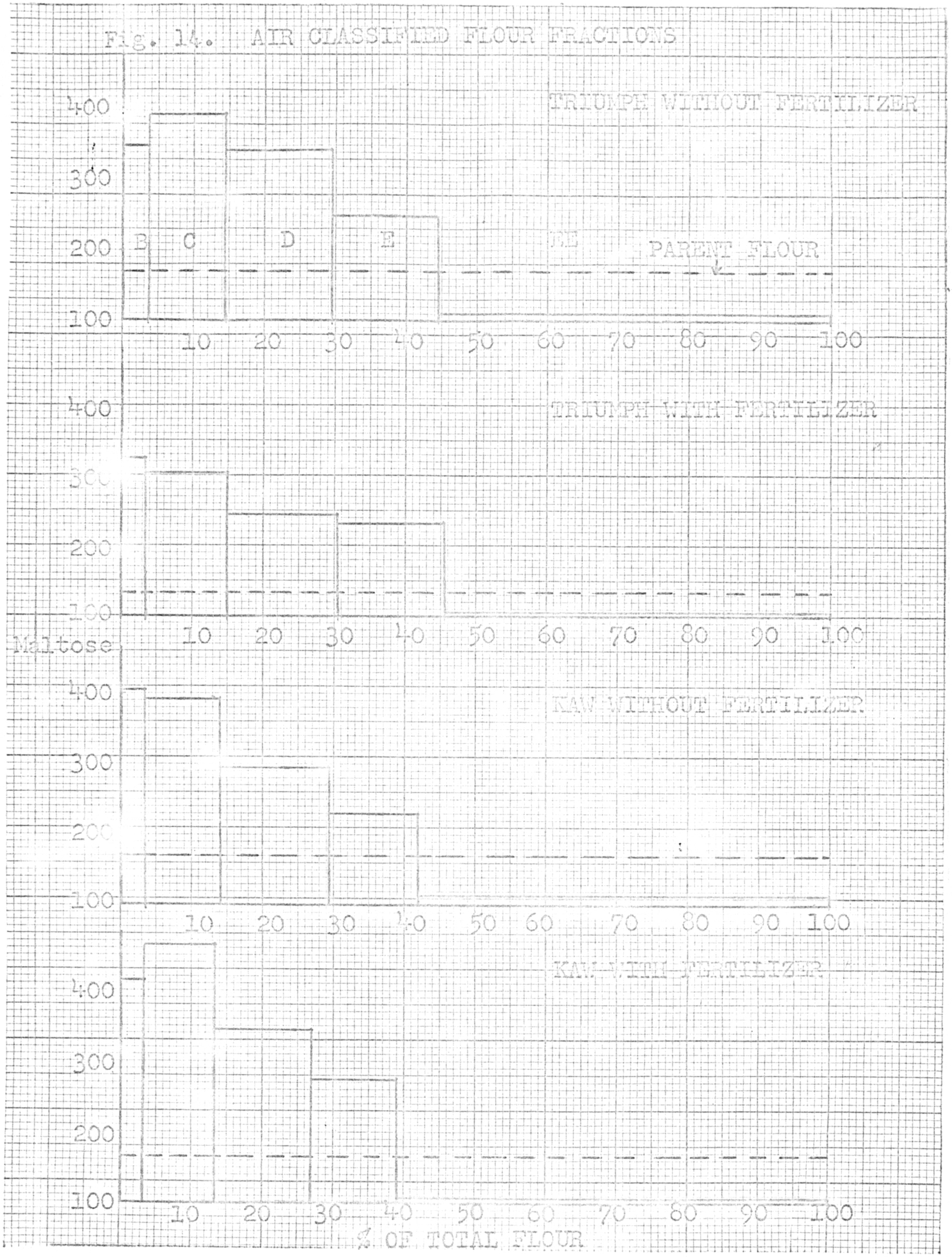


Fig. 14. AIR CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
B
C
D
E
EE
PARENT FLOUR
TRIUMPH WITH FERTILIZER
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
Maltose
400
300
200
100
10 20 30 40 50 60 70 80 90 100
% OF TOTAL FLOUR

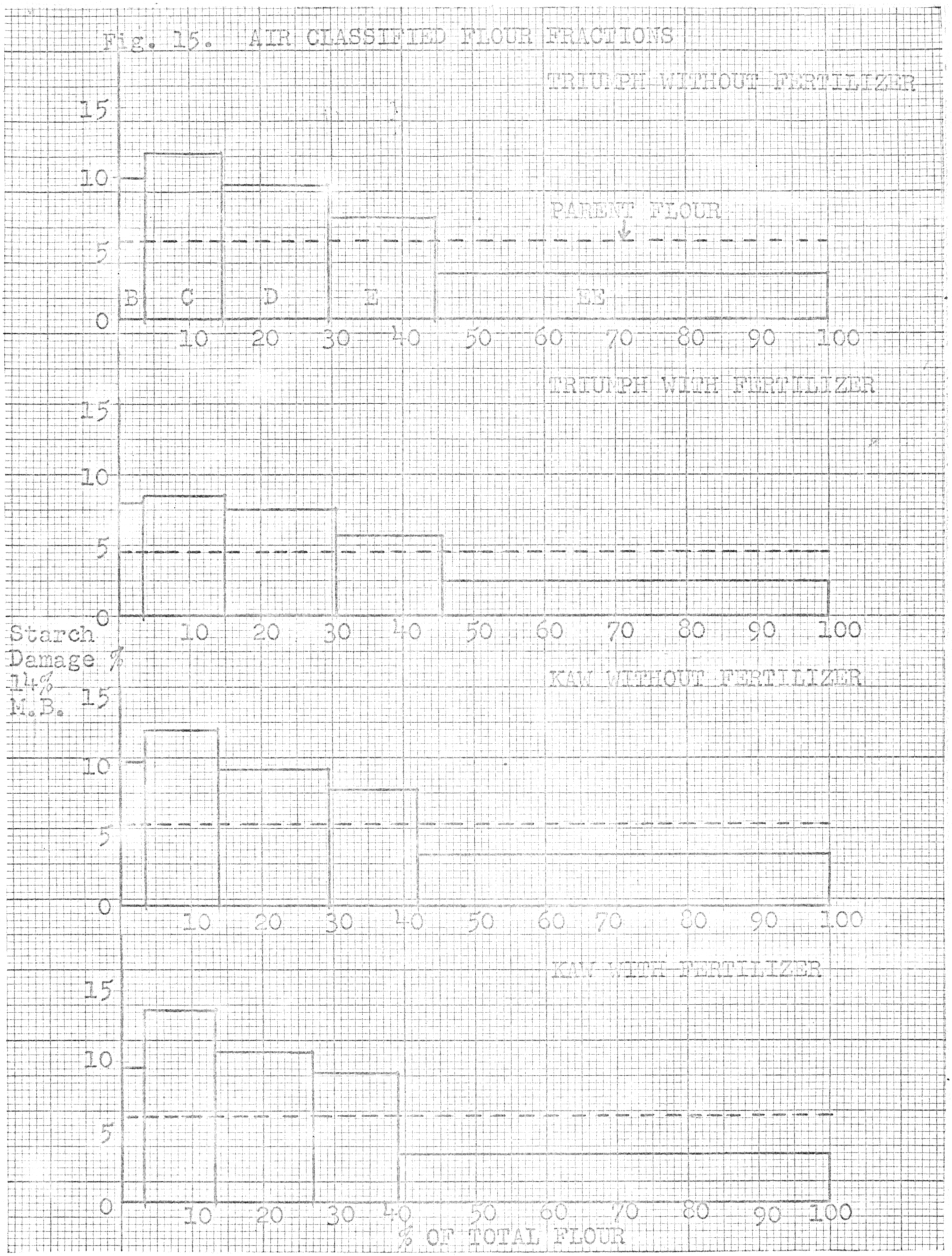


Fig. 15. AIR CLASSIFIED FLOUR FRACTIONS
TRIUMPH WITHOUT FERTILIZER
PARENT FLOUR
B C D E EE
TRIUMPH WITH FERTILIZER
Starch Damage % 14% M.B.
KAW WITHOUT FERTILIZER
KAW WITH FERTILIZER
0 5 10 15
10 20 30 40 50 60 70 80 90 100
% OF TOTAL FLOUR

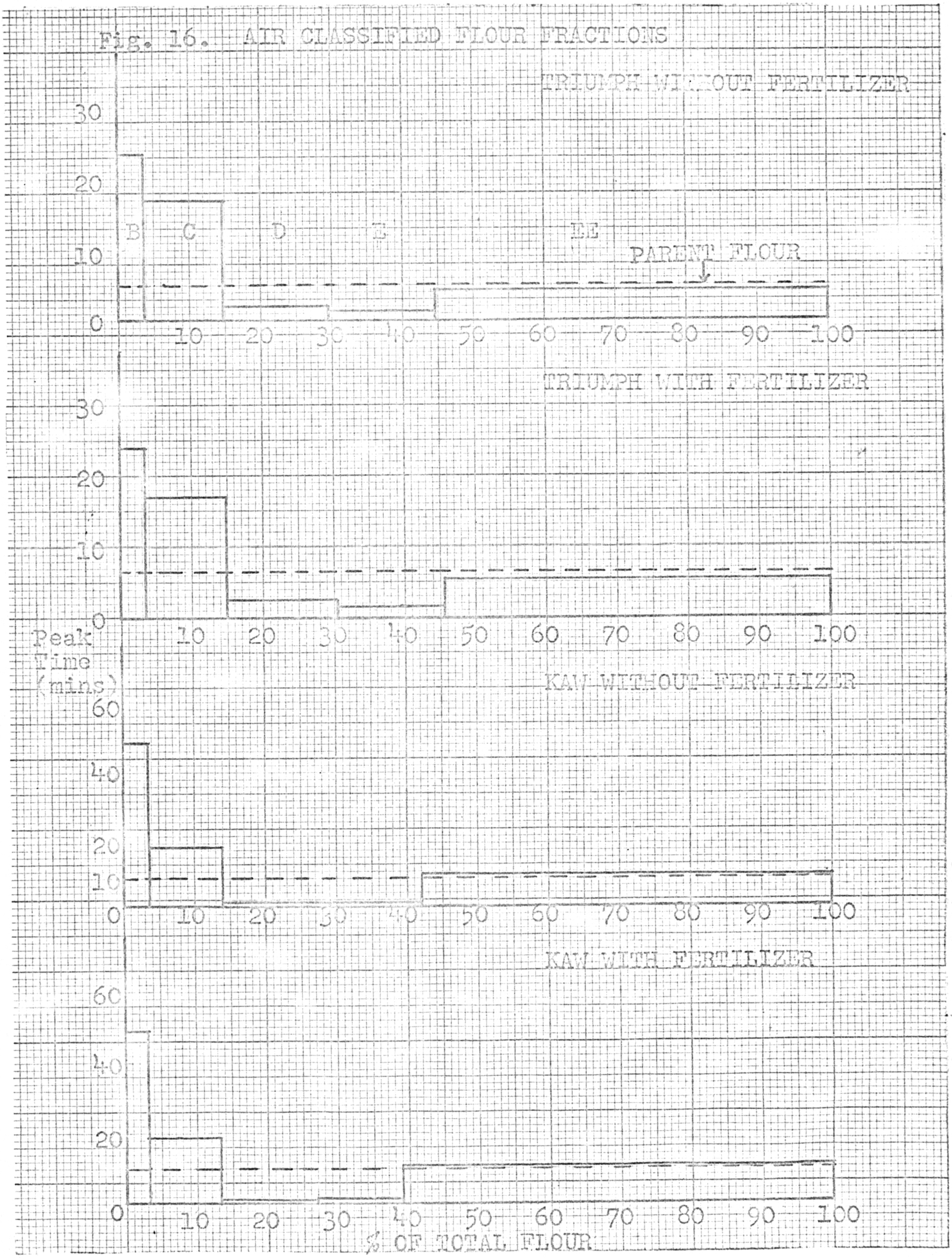
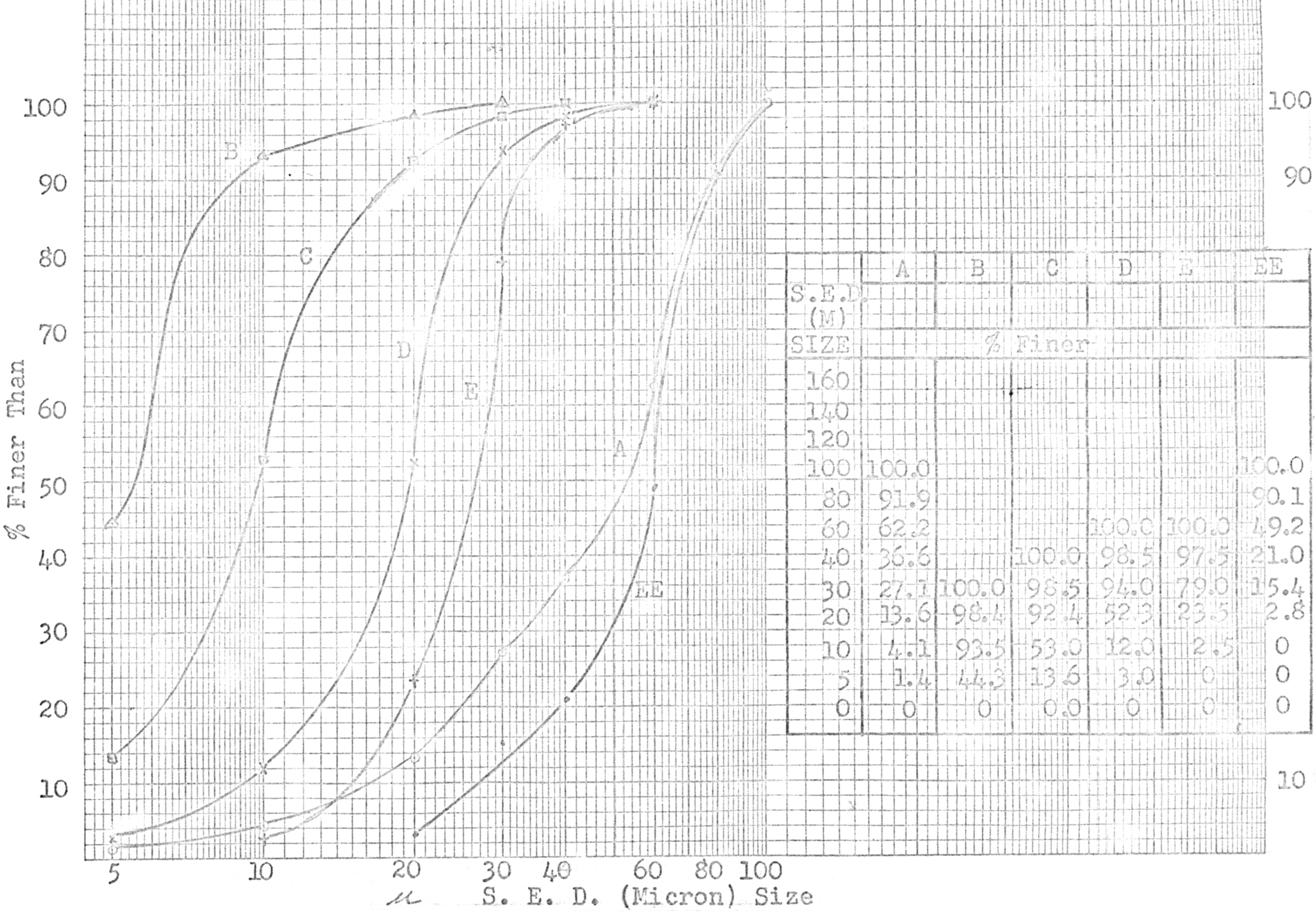


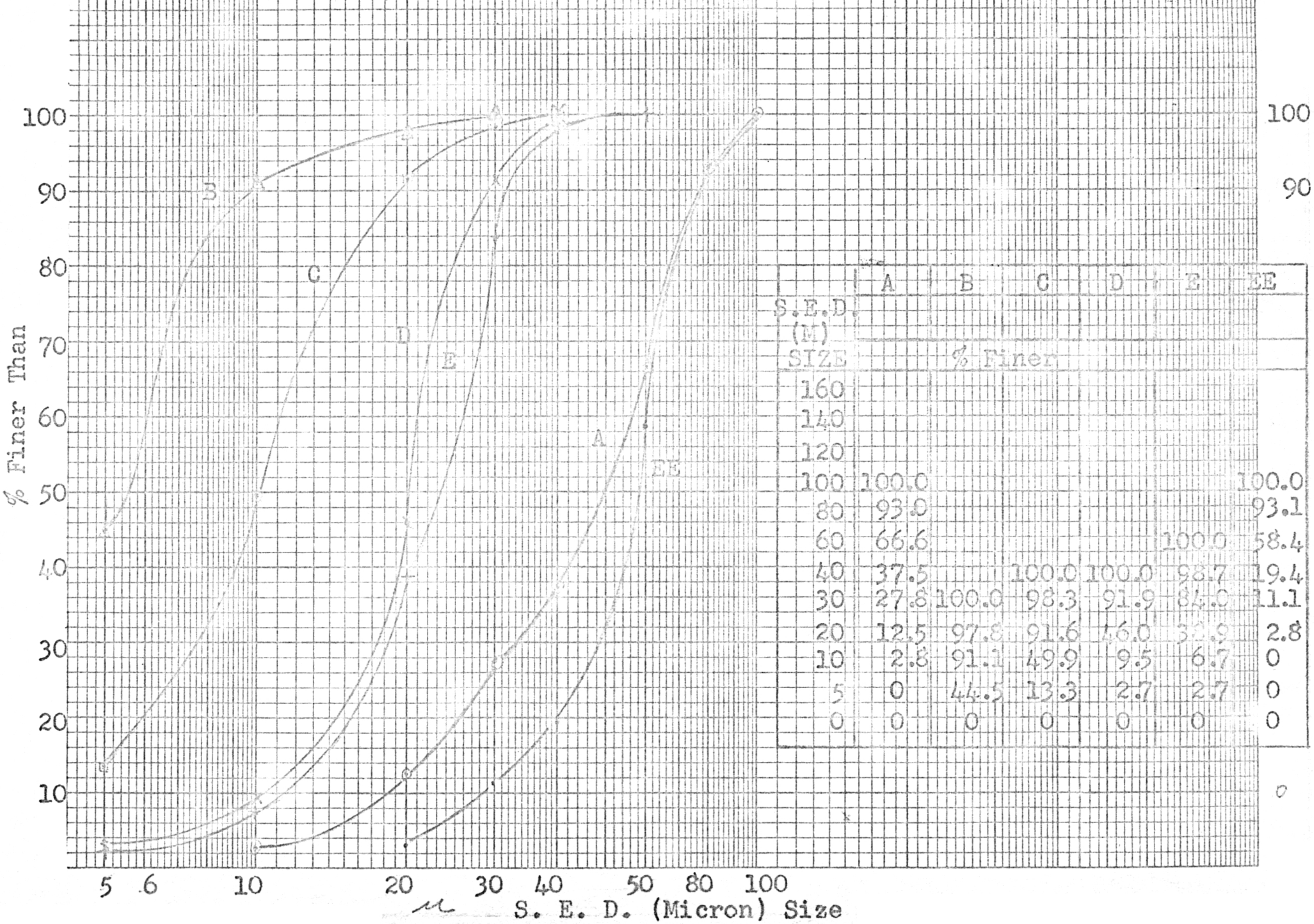
Fig. 16. AIR CLASSIFIED FLOUR FRACTIONS

Fig. 17. WHITBY SEDIMENTATION
5 S.S.S. TRIUMPH WITHOUT FERTILIZER



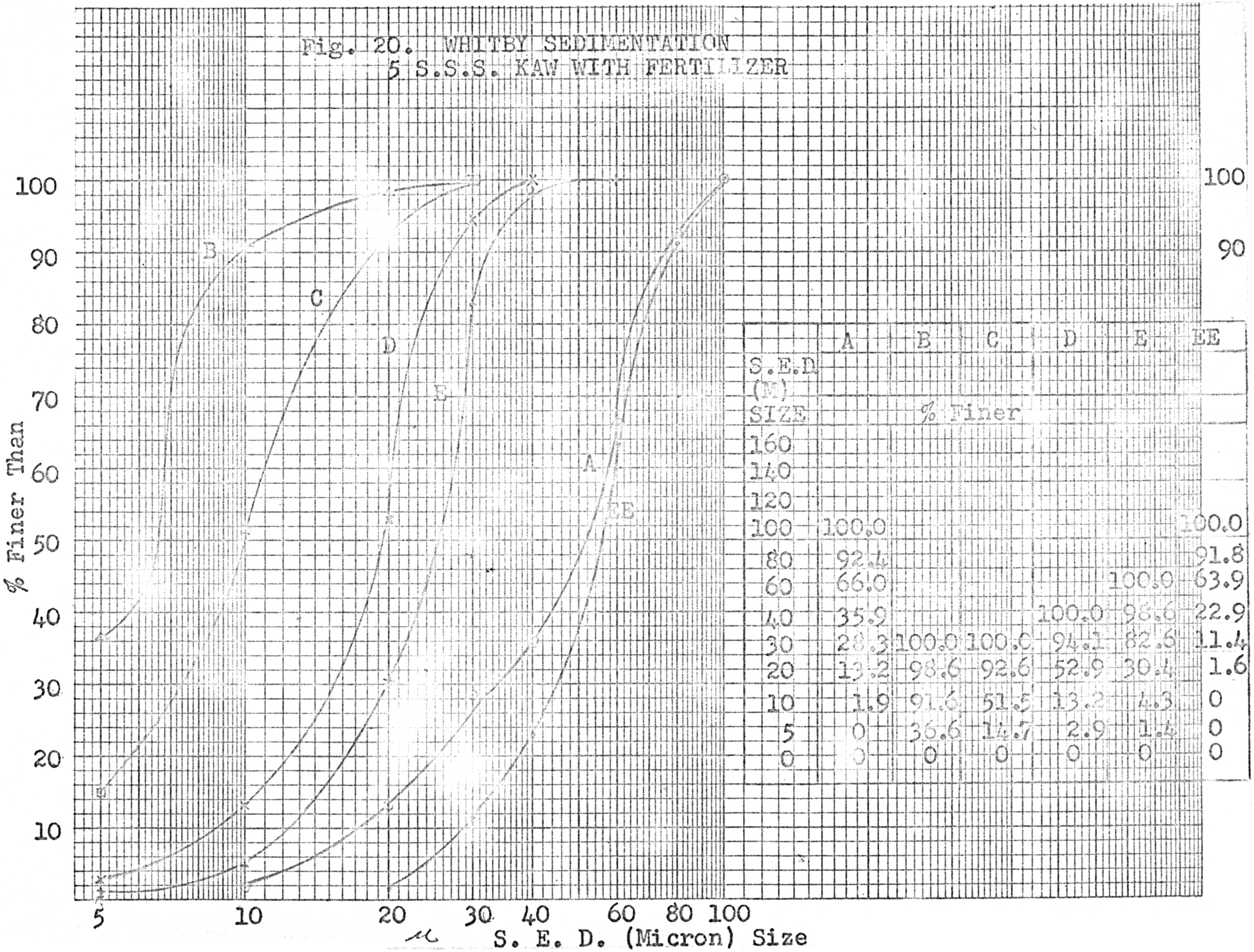
S.E.D. (M) SIZE	A	B	C	D	E	EE
	% Finer					
160						
140						
120						
100	100.0					100.0
80	91.9					90.1
60	62.2			100.0	100.0	49.2
40	36.6		100.0	98.5	97.5	21.0
30	27.1	100.0	98.5	94.0	79.0	15.4
20	13.6	98.4	92.4	52.3	23.5	2.8
10	4.1	93.5	53.0	12.0	2.5	0
5	1.4	44.3	13.6	3.0	0	0
0	0	0	0.0	0	0	0

Fig. 19. WHITBY SEDIMENTATION
5 S.S.S. KAW WITHOUT FERTILIZER



S.E.D. (M) SIZE	A	B	C	D	E	EE
	% Finer					
160						
140						
120						
100	100.0					100.0
80	93.0					93.1
60	66.6				100.0	58.4
40	37.5		100.0	100.0	98.7	19.4
30	27.8	100.0	98.3	91.9	84.0	11.1
20	12.5	97.8	91.6	46.0	[illegible]	2.8
10	2.8	91.1	49.9	9.5	6.7	0
5	0	44.5	13.3	2.7	2.7	0
0	0	0	0	0	0	0

Fig. 20. WHITBY SEDIMENTATION
5 S.S.S. KAW WITH FERTILIZER



S.E.D (M) SIZE	A	B	C	D	E	EE
		% Finer				
160						
140						
120						
100	100.0					100.0
80	92.4					91.8
60	66.0				100.0	63.9
40	35.9			100.0	98.6	22.9
30	28.3	100.0	100.0	94.1	82.6	11.4
20	13.2	98.6	92.6	52.9	30.4	1.6
10	1.9	91.6	51.5	13.2	4.3	0
5	0	36.6	14.7	2.9	1.4	0
0	0	0	0	0	0	0

samples was concentrated in the B and C fractions. The protein content of these fractions was higher than that of the parent flour. The protein content of D and E fractions was lower than that of the parent flour. The coarsest fraction (EE) had a protein content similar to that of the parent stock. High protein was associated with high ash and low protein was associated with low ash. The Zeleny sedimentation value did not show a high correlation with the protein content. The average particle size increased with each successional air-separation stage. As protein content increased from E, D, C to B fraction, the particle size decreased. The fine fractions were lighter in color showing a higher color reading than in the chunk fractions. The maltose values increased with decreasing particle size in Triumph with fertilizer wheat flour and in Kaw without fertilizer wheat flour. This same trend does not appear in Triumph without fertilizer nor in Kaw with fertilizer. Maltose value was low in the lower protein fractions but high in the two higher protein fractions. The starch damage was higher in the fine fractions, especially in B and C fraction. This was probably due to more ruptured starch cells.

The Farinographs, as shown in Fig. 21 and 22, indicated the long peak mixing time was associated with high protein, for the higher the protein, the longer the peak time. Mixing tolerance and water absorption increased with the protein content, but M. T. I. decreased with increasing protein content.

The Farinographs of parents and blends, Fig. 23, indicated that Kaw samples had longer mixing time than Triumph samples, both

Fig. 21. Farinographs of Triumph 5 S.S.S. Fractions.

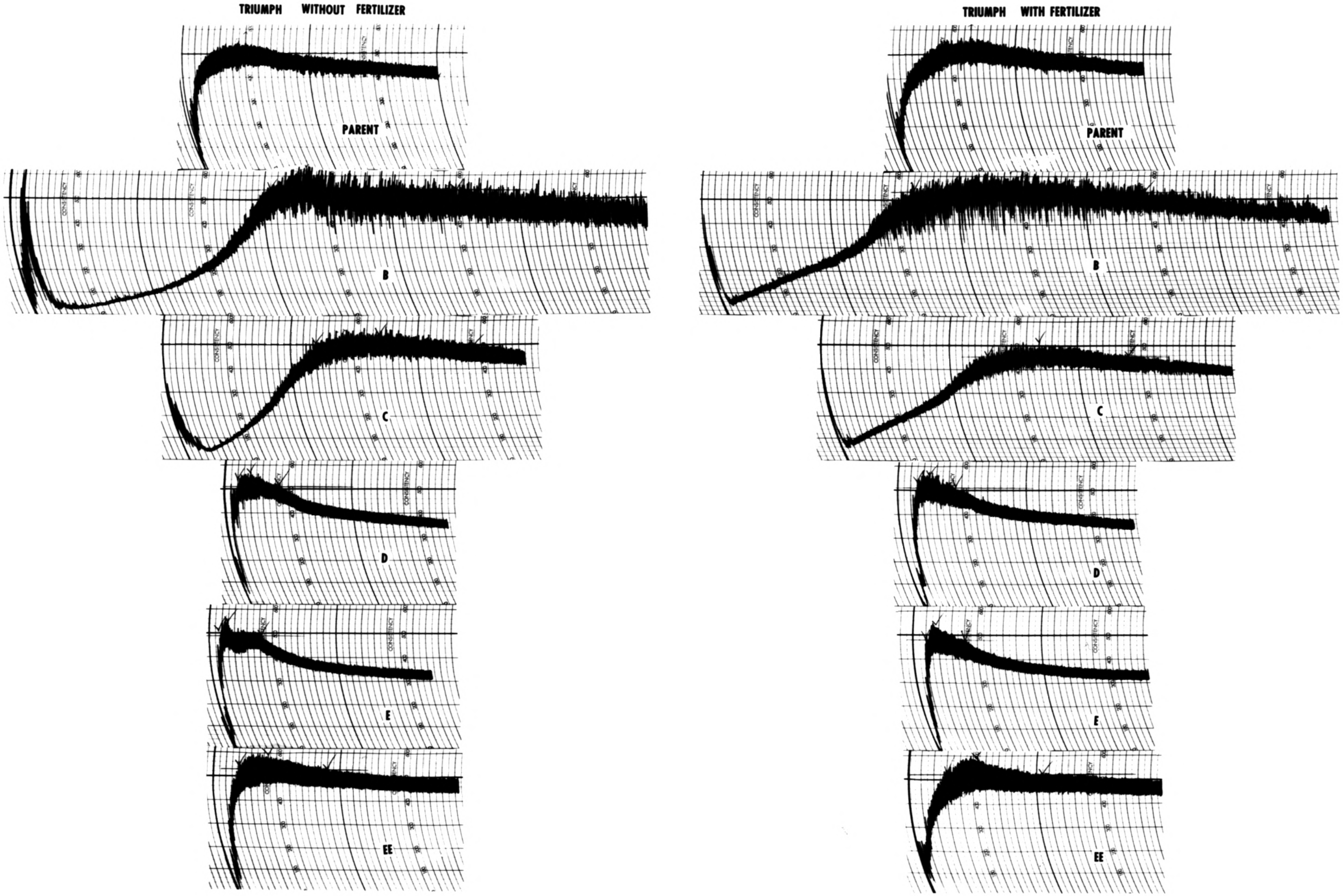


Fig 22. Farinographs of Kaw 5 S.S.S. Fraction.

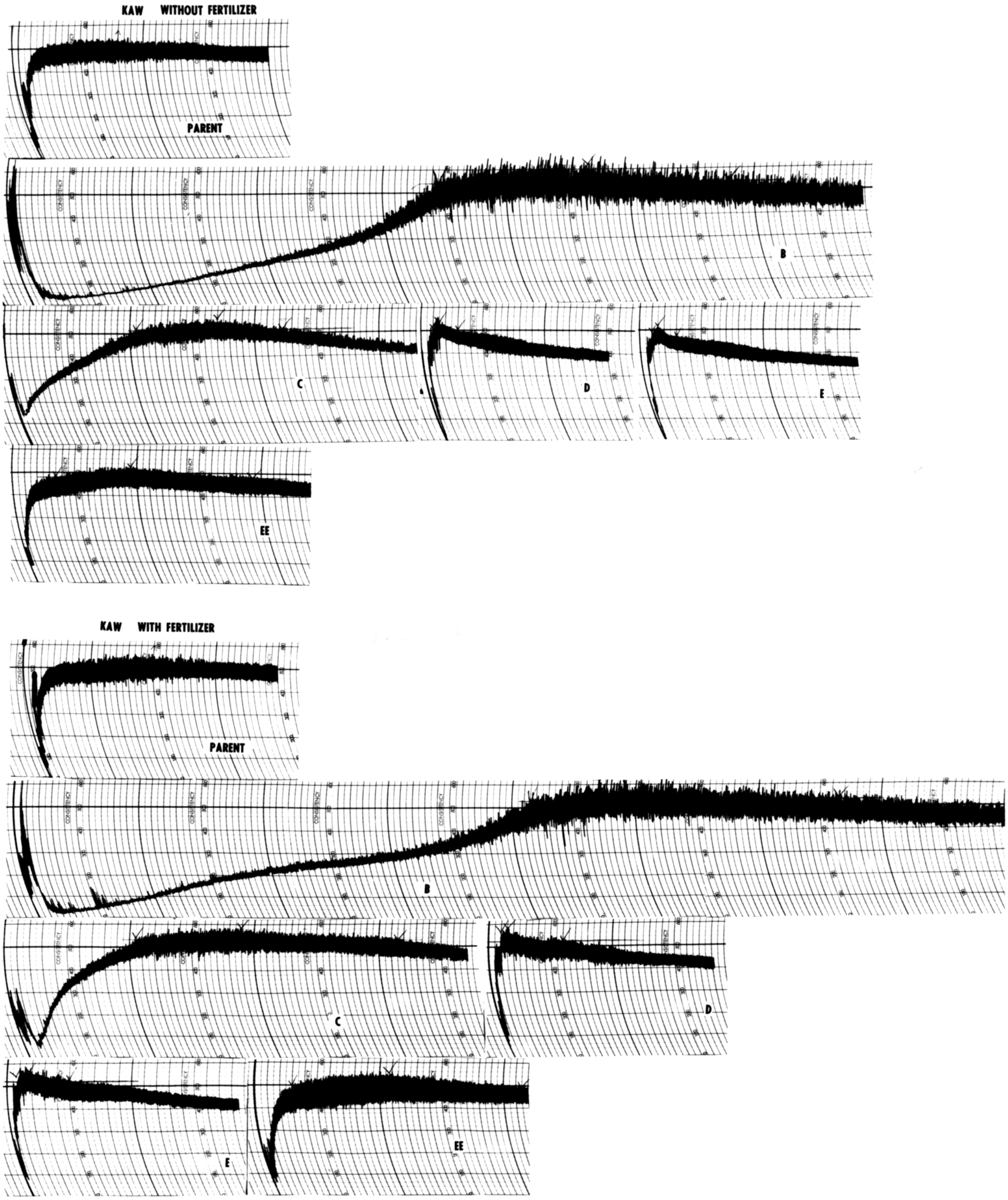
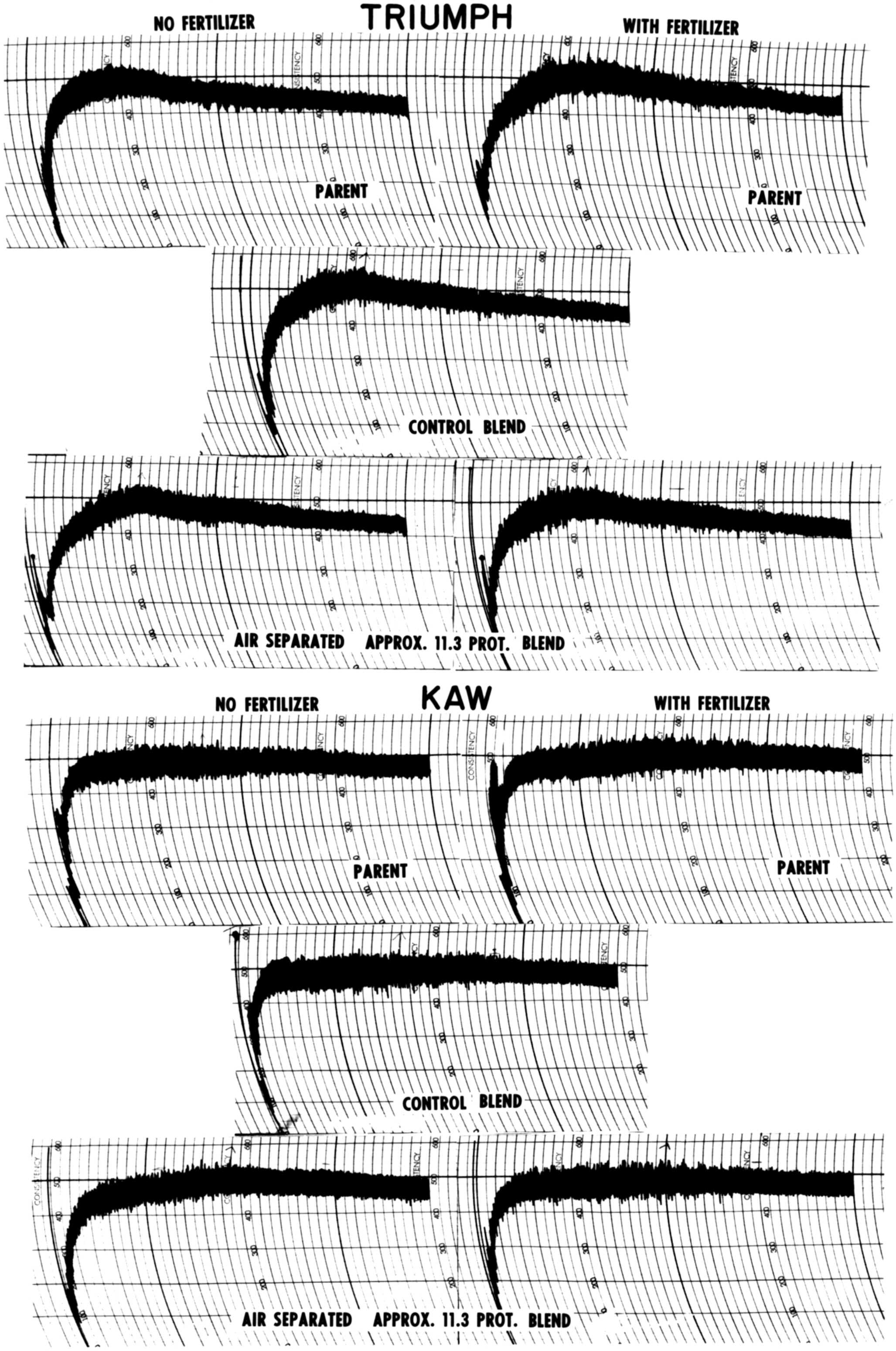


Fig. 23. Farinographs of Parent and Blends.



without fertilizer and with fertilizer, while M. T. I. value was less for Kaw than for Triumph. The same result was obtained with Kaw control blend flour, this flour having a longer peak mixing time then the Triumph control blend flour, while the M. T. I. of Kaw control blend flour was less than that of Triumph control blend flour. The air separated, 11.3 percent protein content, blend flour and Triumph with fertilizer wheat flour, showed the same mixing peak time, but lower absorption and higher M. T. I. than Triumph without fertilizer wheat flour. The Kaw with fertilizer wheat flour showed higher peak mixing time, lower absorption, and higher M. T. I. than Kaw without fertilizer wheat flour. Kaw samples showed longer peaking, lower absorption, shorter M. T. I. value than Triumph samples, both with and without fertilizer.

Results of bread baking of parents and blends are shown in Fig. 24. Physical, analytical and baking data of parents and blends are shown in Table 3. The Triumph wheat flour with fertilizer showed higher volume than the Triumph wheat flour without fertilizer, with protein content of the former higher than that of the latter. This indicated that loaf volume increased with protein content. The same held true for the Kaw samples.

The 11.3 percent protein content blends from each flour were baked, and showed a similar loaf volume among the blends. It was observed that loaf volume and other baking characteristics from the same protein level were more alike 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

Fig. 24. Results of Bread Baking on Parents and Blends.

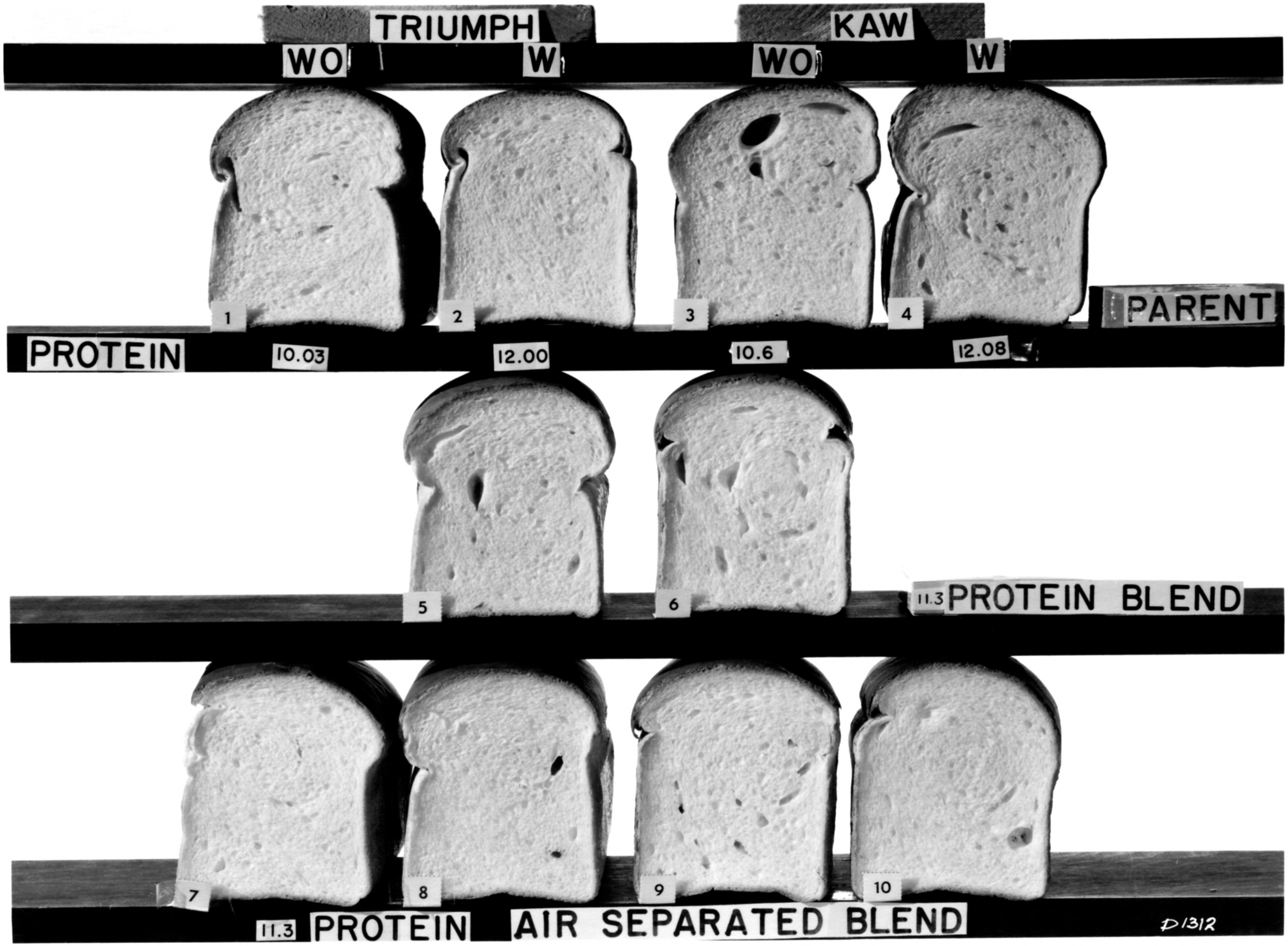


Table 3. Physical, Analytical and Baking Data of Parents and Blends.

	Moist. %	Ash* %	Prot.* %	Zeleny Sed. c.c.	Fisher S.S.S.	Agtron Color 60.5-95.0	Maltose mg/10g	Starch Damage * %	Mixing Peak mins.	Loaf Vol. c.c.	Bread Score
Triumph without fertilizer	11.8	.380	10.03	38.0	19.7	69.5	170	5.50	5.0	2912	84
Triumph with fertilizer	11.7	.370	12.0	54.0	18.0	68.7	134	4.68	6.5	3020	88
Kaw without fertilizer	11.8	.371	10.6	41.0	22.0	67.5	170	5.88	8.0	3037	87
Kaw with fertilizer	11.6	.37	12.08	48.0	23.0	65.0	166	6.20	10.0	3125	87
Triumph control blend	11.7	.351	11.3	47.0	19.1	70.5	144	5.19	6.0	3062	88
Kaw control blend	11.3	.349	11.35	44.0	22.0	66.25	166	6.13	8.5	3055	85
Air-separated Triumph without fertilizer blend	9.9	.376	11.31	38.5	12.7	71.0	178	5.40	6.0	3092	89
Air-separated Triumph with fertilizer blend	11.5	.34	11.46	49.0	17.1	69.25	138	4.89	6.0	3025	87
Air-separated Kaw without fertilizer blend	9.9	.363	11.32	39.0	13.2	70.2	178	6.31	9.5	3040	86
Air-separated Kaw with fertilizer blend	11.25	.364	11.43	45.5	20.0	66.5	178	6.31	10.0	3062	87

* on 14% Moisture Basis.

variable protein levels. From these results, it can be seen that with uniform protein a better evaluation of quality would be possible. This study indicated that similar protein levels of blends from each flour were associated with similar loaf volumes.

The baking score of Triumph with fertilizer wheat flour is higher than that of Triumph without fertilizer wheat flour. Kaw with fertilizer wheat flour and Kaw without fertilizer wheat flour showed the same baking score. The baking score was based on the loaf volume (20 points), crust color (10 points), symmetry (10 points), break and shred (10 points), texture (20 points), grain (20 points), and crumb color (10 points). The baking scores of the blends are close.

The linear correlation coefficients between variance analytical values determined from the fractions are shown in Table 4.

Table 4. The linear correlation coefficient between various analytical value determined for fraction.

	Protein vs Zeleny sedimentation	Protein vs Particle size	Particle size vs Maltose
Triumph without fertilizer wheat flour	0.487	-0.64	-0.963
Triumph with fertilizer wheat flour	0.863	-0.599	-0.99
Kaw without fertilizer wheat flour	0.687	-0.568	-0.982
Kaw with fertilizer wheat flour	0.655	-0.517	-0.977
Combination of four flour samples	0.65	-0.578	-0.927

Table 4 indicates that there was a better correlation between particle size and maltose than between protein content and Zeleny sedimentation, while protein and Zeleny sedimentation showed better correlation than protein and particle size except for Triumph without fertilizer wheat flour. The correlation coefficient between particle size and maltose in Triumph with fertilizer wheat flour was as high as r =-0.99.

CONCLUSIONS

It is difficult to evaluate wheat flours with differing amounts of protein. In order to compensate for this inherent disadvantage, it has been possible to bring flours to the same protein level for a fair comparison of flour quality, independent of protein content by use of air-classification and blending.

Suggestions for Future Work

More than two wheat varieties should be studied to evaluate the quality of wheat flour independent of protein content.

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AIR CLASSIFICATION OF WHEAT FLOURS

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The objective of this study was to control the protein level by air separation.

The four flour samples used for the protein level control procedure were Triumph without and with fertilizer wheat flours, and Kaw without and with fertilizer wheat flours. Air classification; which makes it possible to concentrate the starch and protein into different fractions, was used to make flours with the same protein content.

In the four-stage fractionation using an air classifier, two fine high protein fractions, two low protein fractions and one coarse fraction were separated. After passing through an air classifier, the 10.03% protein Triumph without fertilizer flour had a protein range of 5.64% -- 27.6%; 12.0% protein Triumph with fertilizer had the protein range of 6.78% -- 29.3%; 10.6% protein Kaw without fertilizer had the protein range from 6.95% -- 28.2%; and 12.08% protein Kaw with fertilizer had 7.62% -- 26.0% protein range.

Using a linear correlation coefficient there was a better correlation between particle size and maltose than between protein content and Zeleny sedimentation, while protein and Zeleny sedimentation showed better correlation than protein and particle size except for Triumph without fertilizer wheat flour.

To approximate 11.3% protein, flours were blended from fractions. It was found that Triumph without fertilizer air separated blend was lower in sedimentation value, smaller in particle size, higher in maltose and in starch damage than the Triumph with fertilizer air separated blend. Similar results were indicated in Kaw without and with fertilizer air separated blends, except the Kaw blends had equal maltose and starch damage values. Kaw varieties showed longer mixing peak time, but lower absorption and M. T. I. than Triumph varieties in air separated blends.

Parents and blends were tested for physical dough and bread baking properties. The protein content of Triumph with fertilizer wheat flour was higher than that of Triumph without fertilizer wheat flour; results of the baking test indicated the loaf volume of the former was higher than that of the latter.

The same conditions existed in Kaw with and without fertilizer wheat flours, and indicated the same results. The test showed that higher protein content associated with higher loaf volume.

The 11.3% protein blends from each flour were baked and had similar loaf volumes and baking scores. This indicated that the baking characteristics were more nearly similar with the same protein level than with different protein levels. There were no great differences in baking score and loaf volume among blends.