EVALUATION OF WHEAT TEMPERING AND BLENDING METHODS OF HARD RED WINTER WHEATS UNDER EXPERIMENTAL CONDITIONS

by 4589

ELIESER SALMAN POSNER

B. S., Kansas State University, 1969

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Approved by:

Major Professor

TABLE OF CONTENTS

THIS BOOK CONTAINS NUMEROUS PAGES WITH MULTIPLE PENCIL MARKS THROUGHOUT THE TEXT.

THIS IS THE BEST IMAGE AVAILABLE.

INTRODUCTION

Objectives of the Study

The objectives of this study are threefold; find linear relationships that will help in predicting characteristics of the wheat in the milling process and its flour qualities; to study the usage of the linear related variables in making up wheat blends; and to establish the optimal method of wheat blending during its preparation for milling.

Problem Statement

A wheat lot is a certain amount of wheat, of a certain variety, from one area, in which all the wheat characteristics are the same throughout the lot. Lots are wheat quantities still on the country elevator basis, usually brought as such into the terminal or mill elevator.

A wheat blend is composed according to certain ratios from different lots, to achieve certain desired stable properties of row materials and end products in the milling process. This blending is usually done in the mill, but this service is also given by some terminal elevators for whom economical considerations are some times more important than the consideration of correct blending.

Scott (24) summarizes factors to be taken into account in making up a blend;

(1) Quantities and kinds of wheat available.

(2) Relative capabilities of the wheats to give flour suitable for requirements.

(3) Relative wheat cost.

(4) Possible need to limit percentage of one or more wheats because of some defect.

(5) Relative milling value.

(6) Special conditions to meet customers' requirements.

With a prepared blend the miller has the following objectives in the milling process;

(1) To obtain a maximum of high quality flour by endosperm reduction, after the maximum of it was separated from the bran with a minimum production of bran powder.

(2) To separate the maximum amount of whole germ from the wheat kernel.

(3) Conduct the separation and reduction action with minimum alternation of material characteristics so expected results could be reached.

Blending depends on the multiple characteristics of the wheats, such as varieties, sources, and growing conditions. Although the miller and the wheat blender know a great deal about the wheat characteristics from the different tests results, and much more from their experience and familiarity with the milling operation, they are never sure of the performance of the total wheat composite or the blend in the mill. During the milling process the components of the blend might react differently than when milled separately on the experimental mill. The performance of a blend on a commercial mill might differ from its performance on a laboratory mill.

Besides being interested in the commercial factors in wheat blending, which are not the main concern of this paper, the processing-man is concerned mainly with qualities and deficiencies of the wheat. He is interested in knowing the optimal ratio of wheats in the blend so they will be compatible and give the end products the characteristics closest to those desired. In this study the relations between the wheat lots and wheat blends were taken up, and the manner by which they were affected by wheat tempering prior to the milling process. Observations were made in order to determine to what degree these factors are linearily related.

The machinery for grain processing is in advanced stages, and it can be adjusted with highly precise mechanisms. Lately a mill was assembled where pressure, speed, and differential of grinding rolls are continuously controlled and driven by a hydraulic system. Flow of the products in the mill can also be designed very accurately. The environment in flour mills is controlled and stabilized to certain desired conditions.

Problems start when the mill is fed with raw material. It is necessary to recognize that the material used cannot be stabilized in its temperature or reaction to the environment as a piece of metal or plastic before it is processed. Wheat is a living thing, and changes occurring in it are continuous as in other living things. To mention a few, there are changes in protein, starch, and other constituents which are affected by enzymatic activity. Too much water overnight causes such changes that are at least equivalent to those that will happen to any terrestrial living thing when immersed in water overnight.

There are many changes that occur in wheat during the grinding process, and they are so complicated that it is still hard to comprehend them. Therefore it is difficult to build a mathematical model describing the process of grinding wheat into flour.

To track changes like that it is desirable to analyze effects on the wheat from the moment the miller starts handling it.

It is important to note at this stage, that the work was done on available wheat varieties and that as happens frequently in commercial mills there was no control over the wheats before they arrived at the mill storage bins.

The first stage of handling wheat by the miller is in cleaning to remove all foreign material. In this stage not many significant changes occur in the wheat itself.

In the next stage the wheat is conditioned with or without heat. The object of this stage, from the water entrance aspect only, is that the endosperm gets mellow and the outer part, the bran, gets tougher so it will not be brittle during the milling process.

This paper will not deal with the application of heat to the process of water entrance to the wheat. The conditioning of the wheat used in the experiments was achieved by what is called by Eustace and Farrell (8) cold conditioning or tempering. It requires adding the correct amount of water to the wheat, to best moisture for milling, and letting it stand to allow the moisture to penetrate. The length of time allowed for the wheat in the tempering bins is usually a decision of the miller based on his experience. The two variables that are controlled by the miller are moisture and time.

The miller has to decide what he wants from his mill. This implies taking into consideration all wheat and mill characteristics, making a blend, and tempering it, so that it will give results closest to flour specifications dictated by the consumer.

The present work was done to show how different wheat blending systems react to the addition of water, when tempered to a fixed milling moisture. The following systems were used; (Fig. 1)

(1) Wheat lots were blended, then tempered.

(2) Wheat lots were tempered to milling moisture, then blended.

(3) Lots tempered and milled separately; their flours were blended according to the same percentages as the wheats were blended.

What was not known, was which of these systems, each of which is widely used in the industry, will give the best milling performance and flour characteristics. A final consideration is with which one of these systems can the miller assure himself maximum profit from the wheat blend, by being able to predict flour qualities from the processed blend.

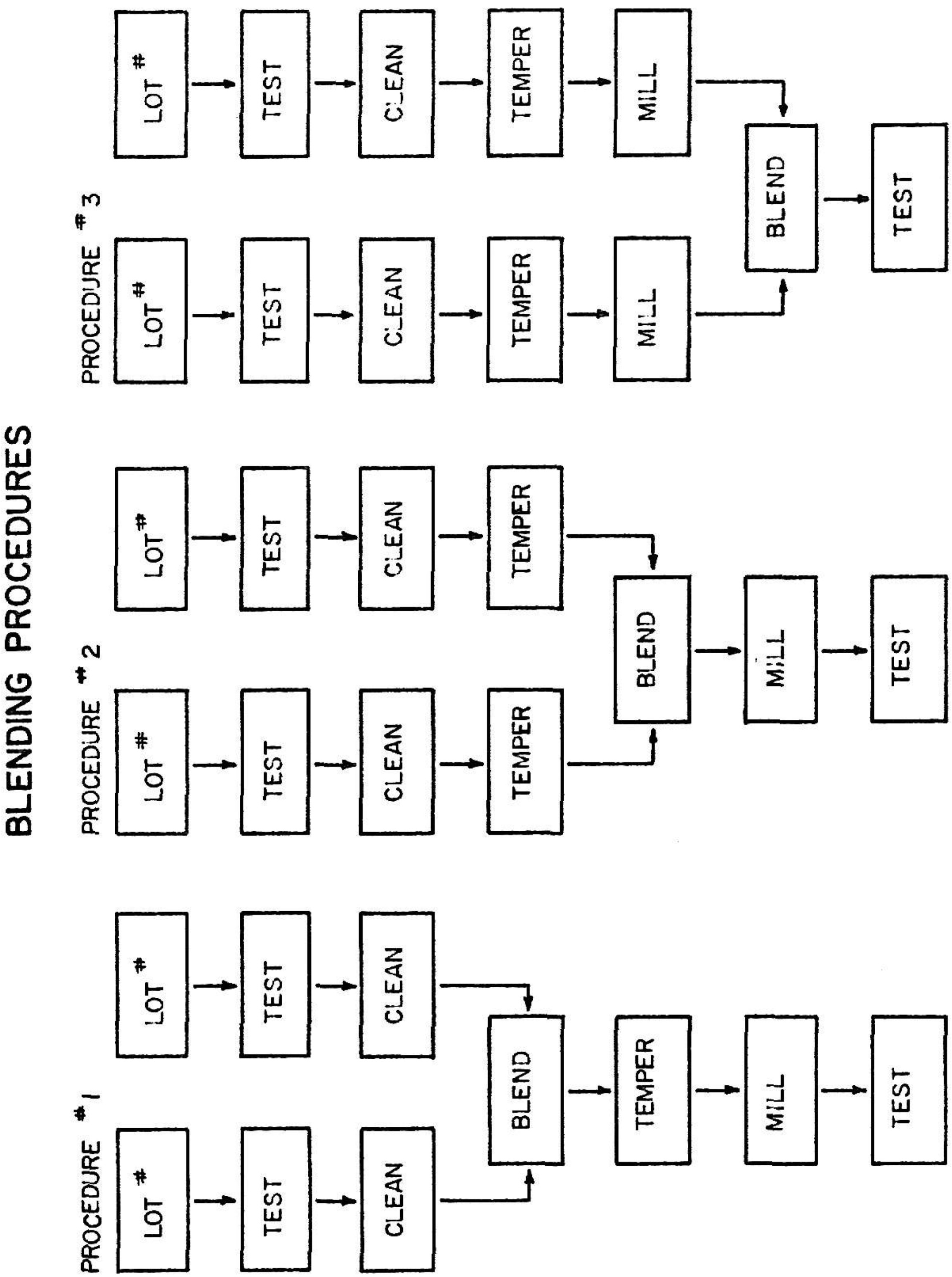


FIG. 1. BLENDING PROCEDURES USED IN THE EXPERIMENTS.

LITERATURE REVIEW

Seibel (25) in 1968 discussed the large amount of work that still needs to be done in the field of wheat blending, which is the first point of major decision in wheat processing. He spoke of the need to set methods for wheat evaluation, so optimum and predicted results can be achieved by wheat blending.

Many authors have dealt with the economical aspects of wheat blending. Schruben, Niernberger, and McGregor (23) (20) (14) analyzed this from the view point of achieving the maximum profit blend for the mill. The importance of this method is in maximizing the difference between the investment in the blend and the returns, rather than lowering the price of the blend. This method when applied to the solving of a mathematical model of wheat blending by linear programming, will ensure a higher profit. It must be kept in mind that basically this method can succeed if the milling and baking processes are used in such a way as to get from the wheats and their products the best results.

Scott (24) emphasized wheat blending as one of the main steps of wheat processing:

> "In milling there are two technical parts of the process far outdistancing the others in importance. The first is blending of wheats and the second is the conditioning or treatment of the wheat preparatory to milling. If these two operations are correctly performed there is little likelihood that anything will be seriously wrong with the flour."

Kuprits (12) made the following observations on wheat blending; better quality flour will result when different varieties from different locations are blended together. The qualities of a wheat variety making up one lot are more significant than when the whole lot originates from the same area.

Wheat blending and the behavior of different blends in the mill were the main considerations of Weber (32). He described systems of preparing wheat blends from different kinds of wheats. Manitoba, Hard Red Winter, Soft Red Winter, and European domestic wheats were used in the blend. Each of these wheats had its particular optimum milling moisture with which the best results could have been achieved when milled separately. Weber used three different methods of preparation. In the first method used wheats were tempered together to a milling moisture, which was 16.5 per cent when fed to the first break. In this case the moisture of the individual components in the blend were; 14.0, 17.2, 17.5, and 18.5 per cent of the Manitoba, Hard Red Winter, Soft Red Winter, and the European wheats respectively. While milling, wheats of softer character were reduced in the beginning of the milling process, and the harder ones in the tail end of the mill. This process was responsible for the placement of good gluten characteristics, typical of the hard wheats used, in the tail end products, and the placement of weak gluten characteristics and baking qualities in the head streams. Using this method the endosperm could not be separated sufficiently from the bran. In the second method, he used the same wheats, but each was tempered separately to a moisture content of 16.5 per cent. Then the wheats were blended and milled. Using this method there was an improvement in the milling characteristics compared to those in the first method. Mill streams were more balanced and their flours had better characteristics. However the bran was not tough enough and broke during the milling process. The third method Weber used involved the tempering of each wheat to its optimum milling moisture: 18-19.5, 16.5-17.0, 16.0-17.0, and 15.0-15.5 per cent for Manitoba, Hard Red Winter, Soft Red Winter, and European wheat respectively. Also in this case the wheats were blended and milled. Here a significant improvement in mill balance, bran separation, and flour of better quality was observed compared to the other two methods.

These results cannot be criticized by any practical miller who milled such different kinds of wheat in one blend. However in the case of the tests performed in the present study, the aim was to find differences in systems of blending, using similar Hard Red Winter wheats. In blending such Hard Red Winter, it is believed that the spread in protein content of the components in the blend should not be greater than 4 per cent.

Swanson (30) used the Buhler experimental mill when he milled wheats tempered to different moisture contents ranging from 12 to 28 per cent. In his study flour yields ranged from 72.0 to 76.1 per cent and ash values from .397 to .430 per cent. At 16 per cent moisture the yield was 73.0 per cent and ash .397 per cent. Observing such results it can be said that milling wheats with 16 per cent moisture content on the Buhler experimental mill can give the closest results to the optimum.

Seibel and Zwingelberg (26) compared results from milling wheats on the Miag Multomat and Buhler experimental mill. They observed that although extractions differed up to 15 per cent, the two mills had the same trend in; extraction, ash, flour color, and coarseness of the produced flour. They stated that with both mills they could show the same significant differences in the milling qualities of the wheats and the baking qualities of their flours. In all their experiments the wheats were tempered to 16 per cent moisture for milling on both instruments.

The reason for the dependence of the milling process on wheat moisture content was dealt with by Robbins (22). He stated that if the moisture content of the tempered wheat is too low the bran will be brittle during the milling process, contaminate the flour and increase it's ash content. On the other hand, moisture that is too high would reduce the bolting capacity of sieves and cause irregularities in the flow, and good middlings would be carried to the tail end of the mill.

The environment in the laboratory while grinding was controlled so it was stable throughout the experiments. Bayfield et al. (4) described the effects that relative humidity and temperature have on flour yields and milling properties. Some of their observations were; flour yield decreases with increasing temperature (about 1/2 per cent per degree °F rise), and the effect is greater with increase in humidity. With higher temperatures flour is coarser than with lower temperatures. With decrease in temperature and increase in relative humidity flour moisture increases. Flour ash and protein were found to increase with decreasing temperature and relative humidity.

Some of the wheat characteristics were found to behave linearily with final and intermediate products. Finney and Barmore (9) established that the major factor accounting for variation in loaf volume within a variety was protein content. They found that the relation between these two factors was essentially linear between the limits of 8 and 18 per cent protein. However there is no indication as to how a wheat protein behaves when the wheat is in a blend with other wheats. Several questions can be asked here; whether the flour protein resulting from the wheat blend relates linearily to the original wheats in the blend, and to what degree do the flour proteins resulting from the different methods of blending relate linearily to bread volume?

Sherwood and Bailey (27) showed that there is a correlation between ash contents of wheats and their flours. The question is raised whether there is a linear relation between ash content of wheat blends and their flours.

Ash content according to Shuey (28), and most milling standards still existing, can be used as a scale for measuring milling performance. (22) (15)

Anderson (2) compared results achieved with the same mill blends from the Buhler and from a commercial mill. In all cases ash was higher in the experimental mill flours but protein was higher in a few of them when compared to the commercial flours. Upon considering his conclusions it seems that it may be possible to compare flours at a certain point on the accumulative protein and ash curves from the experimental and commercial mill.

Mehrotra (15) developed a technique for calculating the value of the different flour grades which can be derived from blending flour streams based on stream analysis in various proportions. This is the Milling Value that was used in the experiments.

Gilmore (10) discussed the need of blending flours from different wheat blends. Because wheat varies in its characteristics, he believed that an operation of flour blending is a necessity in a mill since it gives the miller another check point before he delivers the flour. At this stage the miller could make another adjustment to the specified requirements by blending in flours. Gilmore also found that blending flours by weight gives a more exact blend over the volume method in which certain ratios are used. He based his statement on the fact that all flour evaluation tests were done with weighted materials, and on the fact that the weight of flours coming from the mill varied according to their grade.

It is believed as stated by Niernberger (20) that results achieved by blending of flours, based on protein content, can be predicted very closely. It is possible because the function of the dependent variable, the bread score, behaves linearily if a small adjustment is made. In this case the independent variables in the model were; wheat protein, flour protein, flour ash, loaf volume, farinograph development time, and farinograph valorimeter.

Kuprits (12) recommends wheat blending, instead of flour blending, where the mixing effect has increasing effect with increasing number of lots.

Factors that have to be taken into account at this stage are that milling wheat separately in a commercial mill involves changing the operation from one wheat to another and correspondingly, cleaning house, conditioning and mill adjustment. In addition there are requirements for large storage capacities. Processing a wheat blend on a mill requires a fixed adjustment that is changed only when wheat blends are drastically changed.

MATERIALS AND METHODS

The samples of wheat used in this study were:

(a) For Part I; two Hard Winter Wheat varieties from a commercial mill designated by N-1-1 and N-1-6, with 14.8 per cent and 11.3 per cent protein respectively. The blends were designated with the codes B-1-1 to B-1-10, B-1-11 to B-1-20, and B-1-21 to B-1-30 for the three systems of blending respectively.

(b) For Part II; two Hard Winter Wheat varieties. Bison and Parker, from Agronomy Research Farm, Kansas State University, which were stored for about twelve months in K.S.U. Pilot Mill bins. They were designated by the code; Let 44 for Bison, and Let 45 for Parker. Their protein contents were 12.7 and 14.3 per cent for Bison and Parker respectively. The blends were designated with the codes B-2-1 to B-2-6, B-2-10 to B-2-15, and B-2-19 to B-2-25 for the three systems of blending respectively.

The product of blending in Part I and Part II of the experiment are presented schematically in Plate I.

Part I differed from Part II basically by the fact that the wheats, and wheat blends of the former were milled on the Buhler Experimental Mill and those of the latter part were milled on the Miag Multomat Experimental Mill.

The following tests were performed on the original dry wheats, as well as on the tempered wheats before they were milled separately or as blends; Test Weight, Thousand Kernel Weight, Pearling Value, Wheat Size Test, Moisture, Protein and Ash. They are discussed in the order they appear in Tables 11 to 13, and 17.

Test Weight; Determinations were made with a quart kettle using a beam scale according to the standard method outlined by the U.S.D.A. (31). Results are expressed by weight in lbs. per Winchester Bushel.

One Thousand Kernel Weight; Weight was determined with an electric seed counter using 40 grams of whole wheat kernels. From the number of kernels in 40 grams the weight of 1000 kernels was determined.

Wheat Potential Yield was outlined by Shuey (29). Two-hundred grams of the sample were sieved on a Ro-Tap shaker using the following Tyler Standard sieves; a 7 mesh wire, a 9 mesh wire, and a 12 mesh wire. The sample was then shaken for 3 minutes. The overs were recorded as percentage of the total weight of the sample and were assigned the factors 78, 73 and 67 for the overs of 7W, 9W and 12W respectively. The sum of the products according to Shuey (29) gives the potential yield of the flour from the wheat.

The Pearling Test was outlined by McCluggage (13). In this test a 20 gram sample of hand picked whole wheat kernels was pearled in a Strong-Scott barley pearler for 60 seconds (the broken kernels were picked out). The pearled grain was sifted by hand on a 20 wire Tyler Standard sieve to remove all the dust and breakage. The pearling value was the remaining pearled kernels expressed as per cent of the original weight.

In Part I of the experiment, the dry wheats were cleaned on a Carter Dockage Tester. Ten blends were made according to percentages listed in Table 1. These were determined by the model developed by Niernberger (20).

After blending for 15 minutes the wheats were tempered to 16 per cent moisture, and left standing for 18 hours. Other 10 blends with the same relationships between N-1-1 and N-1-6 wheats were made from quantities of these wheats after water was added to them to raise their moisture content to 16 per cent and tempered for 18 hours. The two original lots from which the flour blends were made were also tempered for 18 hours to 16 per cent moisture.

Table 1. The percentages of lots contained in blends milled on the Buhler.

Protein % 14% m.b.	N-1-6 %	N-1-1 %
9.53	100.0	--
9.75	94.0	6.0
10.00	87.2	12.8
10.25	80.4	19.6
10.50	73.6	26.4
10.75	66.8	33.2
11.00	60.0	40.0
11.25	53.1	46.9
11.50	46.3	53.7
11.75	39.5	60.5
12.00	32.7	67.3

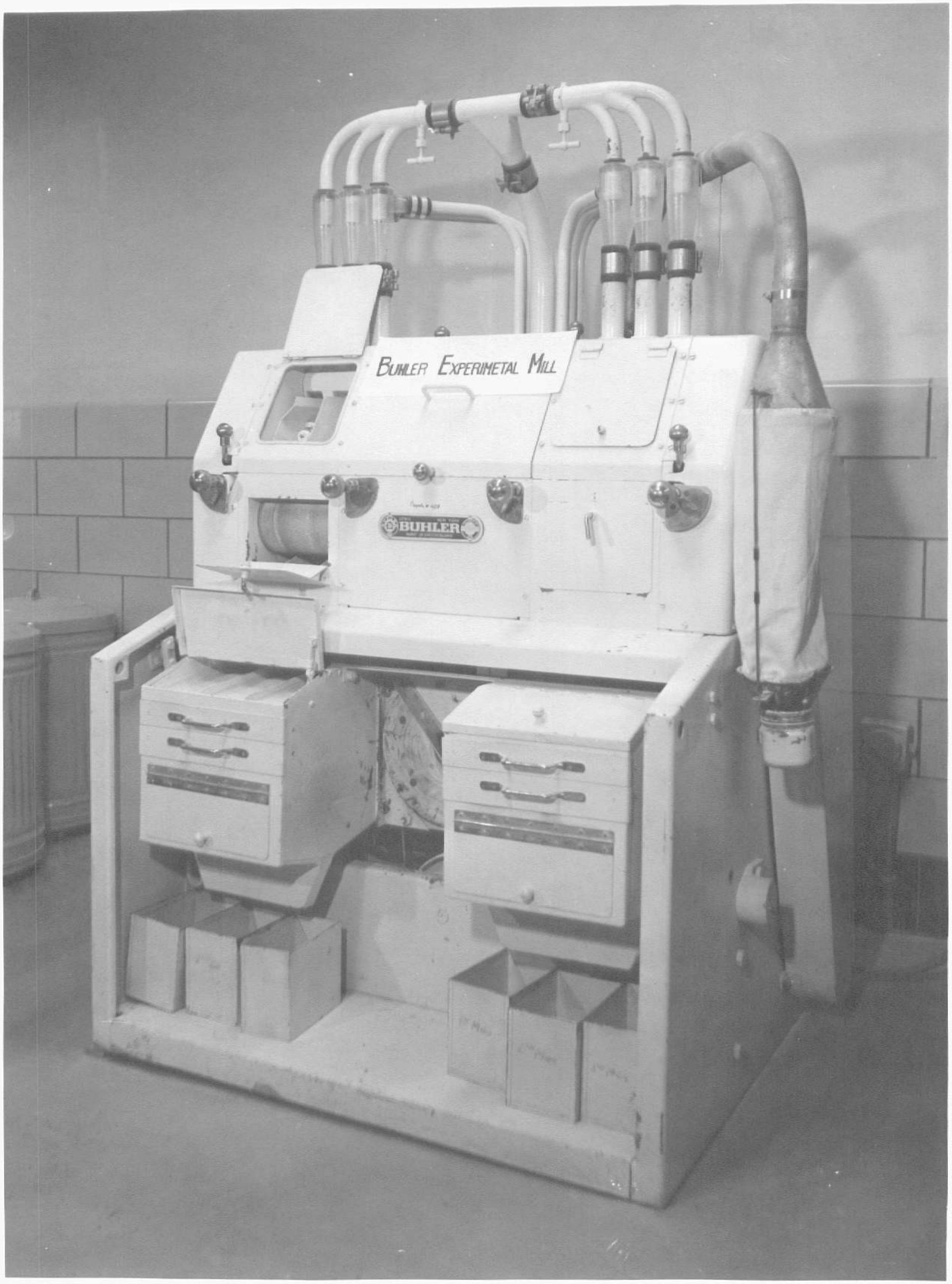
These wheat lots and blends were milled on the Buhler Laboratory experimental Mill (Plate I), of pneumatic type. The flow (Fig. 2) consisted of three brakes and three reduction rolls. These rolls were unchanged for the whole experiment. The rolls were set in a decreasing distance from .013" to .003" in the breaks and .001" to .000+" in the reductions. The rolls had a differential of 2:1 with the fast roll running at 540 rpm. The break rolls had the following corrugations:

First break 18 corrugations per inch
Second break 22 corrugations per inch
Third break 26 corrugations per inch

Six flours were collected from each run as well as bran and shorts. Flour streams, shorts and bran were weighed and per cent flour yield was calculated on the total product basis. Each stream was analyzed for moisture,

EXPLANATION OF PLATE I

Photograph showing the Buhler experimental mill used for milling of wheat samples.


BUHLER EXPERIMETAL MILL
BUHLER

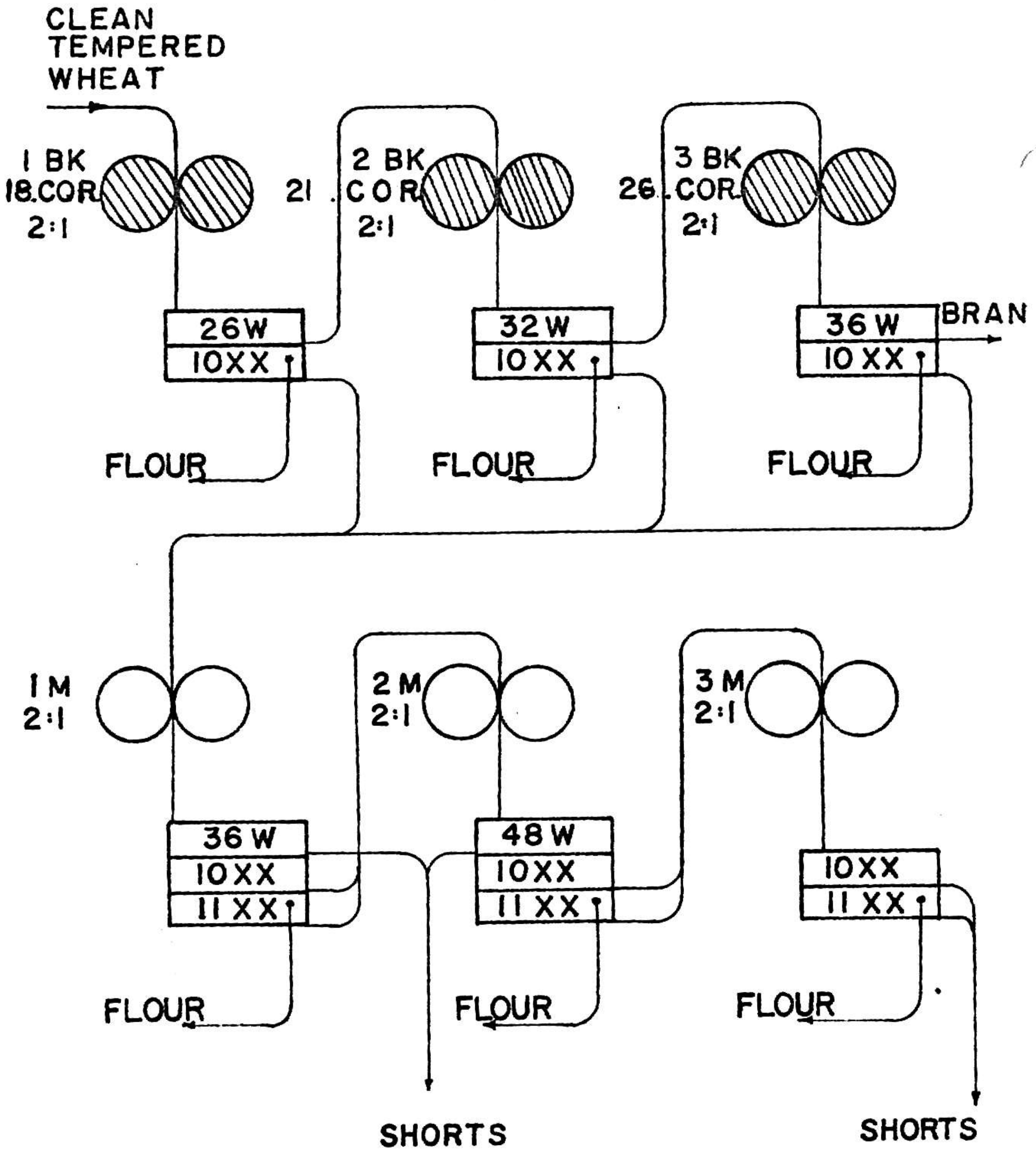


FIG. 2.

FLOW SHEET FOR BUHLER EXPERIMENTAL MILL

protein and ash. These samples were taken from a 1/3 of each stream by weight. The rest of the 1/3 was discharged, to keep the original ratio among the streams in the straight grade flour. The straight grade flour was achieved by blending 2/3 of each stream in a Sterwin blender for 15 minutes.

Part II of the experiment was carried out with two hard winter wheat varieties, Bison and Parker of 12.7 and 14.3 per cent protein respectively. The two wheat varieties were cleaned on the Kansas State University Pilot Mill Cleaning House (Fig. 3). The wheat cleaning flow consisted of a permanent magnet, pneumatic lift aspirator, milling separator, dry stone separator, gravity table, disc separators (oat and cockle), Entoleter scourer-aspirator and a duo-aspirator. The grains were conveyed with a screw conveyor, a bucket elevator and pneumatic lifts. Then the wheats were scoured on a Forster Scourer.

They were combined into blends with two ratios; the first consisted of 25 per cent Bison and 75 per cent Parker, and the second of 50 per cent Bison and 75 per cent Parker. In this case, as in the blends milled on the Buhler, the scheme of three types of blending was followed (Fig. 1). Three replicates were made for each ratio and type of blending. Totally there were 12 blends to be milled besides two wheat lots. Each sample was of three bushels.

Miag Multomat Experimental Mill

These samples were milled on the Miag Multomat Laboratory Mill. Equipped with a pneumatic conveying system and a BIF (Omega) gravimetric feeding apparatus, the mill was fed about 42.9 kg/hr or 94.6 lb/hr. The flow (Fig. 4 and Plate II) consisted of three breaks, five reduction passages, and two grading sections; one receiving overs of flour cloth from the first and second breaks, and the other the overs of the first mids flour sieves. The break rolls had a differential speed of 2:1, where the fast roll operated at 325 rpm. Corrugations are shown in the mills flow sheet.

Products from the mill were; ten flour streams, one bran, two shorts classified as break shorts and reduction shorts, and a red dog (a mill feed) at the tail end.

In the beginning of each milling day a mill warm up was made for 20 min.

The milling procedure was as follows;

The feeder was adjusted to the desired quantity of 42.9 kg/hr for each respective sample. The wheat was then fed to the mill and the breaks were adjusted to the following break releases; 40, 50 and 60 per cent through a 20 wire for the first, second and third break respectively. The setting of the reduction rolls was not changed throughout the experiments. After adjustment the entire mill was stopped. Leaving the machine under full load, all products were emptied from the collecting boxes. The mill was started again in reverse sequence. When a sample of wheat finished passing through the feeding hopper the mill was stopped again under full load.

Operating the laboratory experimental mill in this way, it was believed that it would prevent variations in the milling effect on the intermediate products and by that prevent error in uniformity of products. Another error that can be prevented by this procedure is the variation in the total products from the mill. Such an error can be caused by unequal cleaning out of the mill after each sample. Because of the possibility of easy adjustment of breaks the usage of the Multomat in this part of the experiment, eliminated other variables in the experimental milling of the blends. Some of the changes were in the roll's temperature during milling, and in the size of the

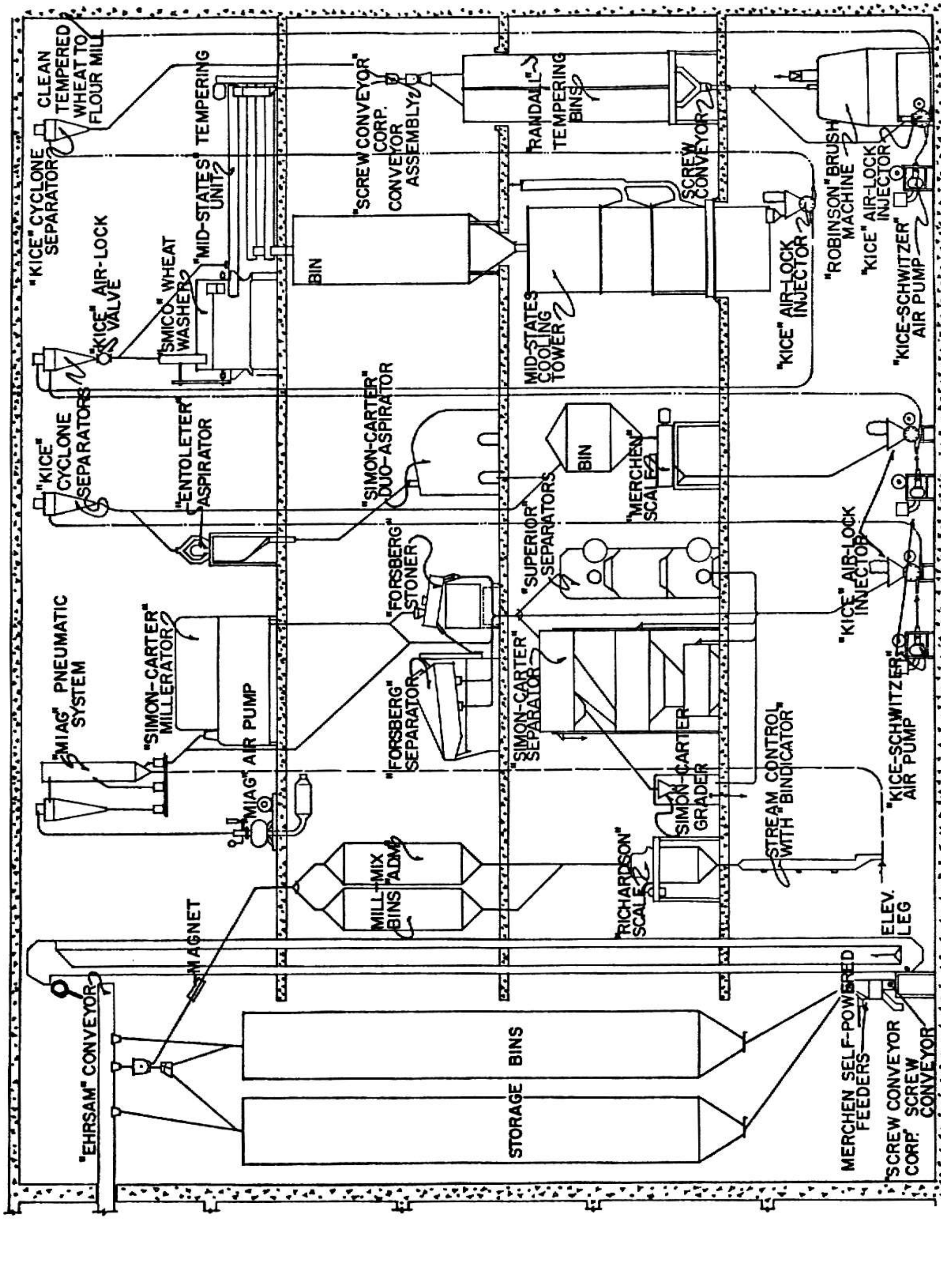
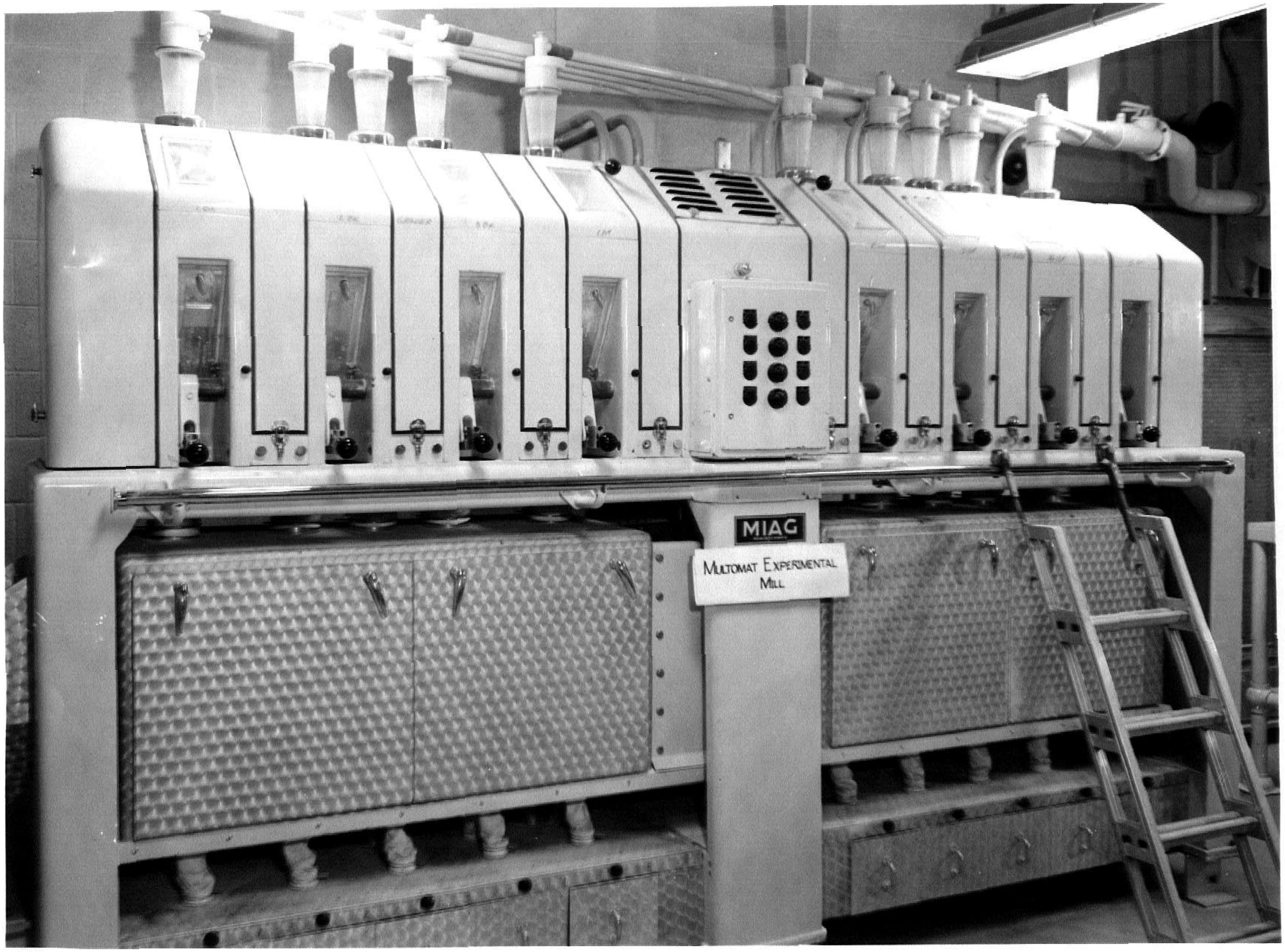


FIG. 3. KANSAS STATE UNIVERSITY CLEANING HOUSE

EXPLANATION OF PLATE II

Photograph showing the Miag Multomat experimental mill used for milling of wheat samples.

PLATE II



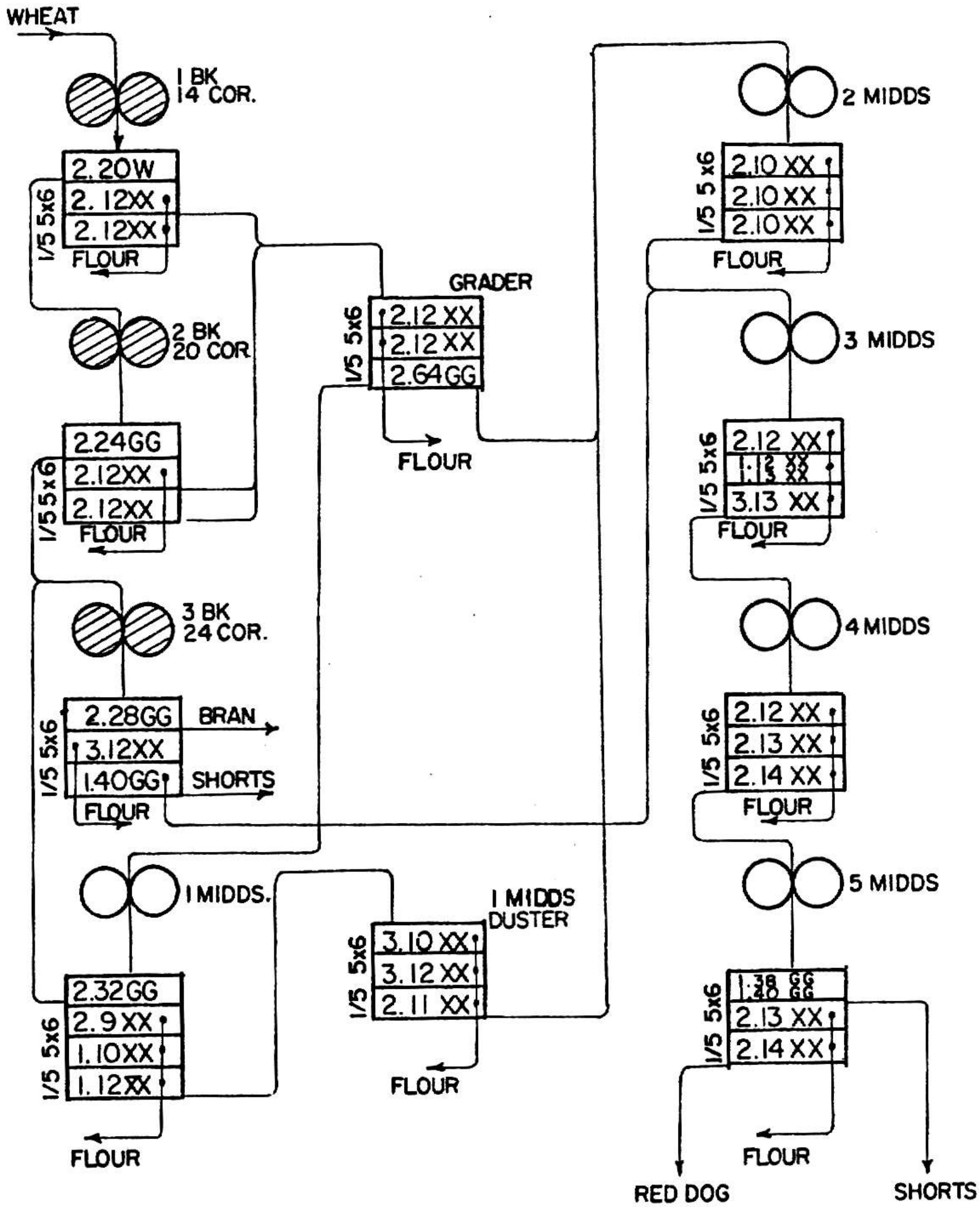


FIG. 4.

FLOW SHEET MIAG MULTOMAT EXPERIMENTAL MILL wheat. Also, larger numbers of end products (leaving the mill) produced by the mill brought the experimental milling procedures closer to commercial milling.

All ten flour streams and the four feed streams were weighed separately to calculate the percentage of the streams and the total flour yield. A 25 to 30 gram sample from each flour stream was taken and analyzed for protein, moisture and ash, and reported on 14 per cent moisture. The straight grade flour from each sample milled was made by blending all the individual flour streams in a Wenger batch blender.

Moisture, protein and ash of wheats as well as that of their milled products were determined by the procedures outlined in the American Association of Cereal Chemists "Cereal Laboratory Methods" (1).

Cumulative Ash and Protein: When rate of flow, percentage of ash and moisture are known for each flour stream, valuable calculations are possible. Ash percentages are converted to ash sample would contain if moistened or dried to 14.0 per cent moisture. The individual flour streams are arranged according to ash content, with lowest ash flour first. Starting with the two lowest ash streams, a series of calculations are made to determine ash content from blending two streams. Then ash of a new blend, consisting of the two flours plus the quantity of a third flour higher in ash content is calculated. In a similar manner data for cumulative protein were calculated. The cumulative ash curve showed the ash distribution characteristics of the milling process. Minimum area under the curve, and a rather flat curve, up to 70-75 per cent extraction, will show close to optimal milling process. Usually a curve that rises rapidly means that the tail end of the mill is overloaded. This method is outlined by Farrell and Ward (8) and by Wissmar (33).

Milling Value: Flour streams from a mill can be blended in various proportions to produce different grades of flour. (15) The cumulative ash and per cent of patent, first clear and second clear flours can be calculated by use of stream analysis. After assigning monetary values of 5.00, 4.20, 3.70 and 1.70 dollars to patent, first clear, second clear and feed, respectively, the produced percentage of each product was multiplied by its price. The summation of these products gave the Milling Value.

The following tests were determined on the straight grade flours. The tests are discussed in the order they are reported in Tables 14 to 16, 18 and 19.

Gluten quality characteristics of the flours was determined by a sedimentation method named "FY" (7), patented by Japan Bread Science Association. It is based on the fact that wheat gluten is known to exhibit a strong water absorption, particularly when mixed with a diluted acid, which decreases its specific gravity. A wheat gluten of better baking quality exhibits greater water absorption, therefore its rate of sedimentation tends to decrease. The rate of sedimentation is measured by reading the height of the sediment in a graduate cylinder after certain time intervals. The "FY" values derived in a study, of Hard Winter Wheat, conducted by the Japanese Institute of Baking (11) were found to be closely interrelated with bread score. These values were higher than the cases representing correlation of Zeleny Sedimentation with bread score.

To perform the rheological tests on the flours the Farinograph and Extensograph were used. The following determinations were made from the Farinograph curves, according to AACC Methods (1) 54-21.

Absorption; This is the percentage of water required to center the curve on the 500 Brabender Unit (BU) line at the maximum consistency of the dough.

Arrival Time; This is the time required for the curve to reach the 500 BU line from the beginning of the curve. It gives the rate of hydration.

Peak Time; This is the time required for the curve to reach its full development or maximum consistency. Long peak times are usually associated with strong wheats.

Stability (or Tolerance); This is the time that the curve remains on the 500 BU line and is measured from the arrival time to the departure time. Longer tolerance would indicate that the flour can stand more abuse or mixing and longer fermentation.

Mechanical Tolerance Index (MTI); This is an indication of how fast a flour will break down after it has reached its full development time and is measured in BU from the height of the curve at its peak to the height of the curve five minutes after the peak.

Valorimeter; This is the term commonly used in reporting a farinogram. It is a numerical value based on a logarithmic function of the peak time in relation to the breakdown of the dough 12 minutes after peak time. The valorimeter reading is easily determined by placing a logarithmic template over the farinograph curve and noting where the lines intersect. Higher figures indicate a stronger flour and the lower figures indicate a weaker flour.

Test procedures with the extensograph were made by preparing three doughs which were rested for different time lengths before they were stretched. These procedures differ from the AACC method (1) 54-10, which stretches the same dough after it is allowed to rest for a desired period.

In the tests performed with the flours milled on the Buhler experimental mill the doughs were stretched after 15, 30 and 45 minutes of rest.

The following determinations were made from the extensograph curves;

Length of Extensogram; This measurement in centimeters indicates the extensibility of the dough and is measured from the start either to the maximum Force (E1), or to complete rupture (E2).

Height of Extensogram (F); This measurement in BU indicates the maximum resistance of the dough and force applied to overcome it.

Area Under Extensogram (A); This measurement in cm^2, taken with a planimeter, gives the total area under the extensogram.

All the above measurements were taken for each of the curves; these values, as well as numbers found by formulas, were correlated to bread score.

The loaves were baked from the flours according to the method developed by the Department of Grain Science and Industry. Scoring of the breads, too, followed the procedure described in detail by Niernberger (20). Loaf volumes were determined by the seed displacement method, with the volume expressed in cubic centimeters (21).

RESULTS AND DISCUSSION

The experimental results of the wheat blends and flours are shown in Tables 11 through 19.

From the analysis of the flour streams of each sample milled on the Miag Multomat, cumulative ash and protein curves were drawn in order of increasing ash. Six curves of each ratio were drawn together in Figures 6 and 7. Three replicates in each of these figures differ from three other replicates in the procedure of wheat blending and tempering before milling. Figure 5 shows the protein and ash cumulative curves of flour from the original wheats. It is clear that the resulting ash curves from the blends prepared from wheat lots before they were tempered were generally more flat and the area under them was smaller than in the curves of blends from lots after they were tempered. In the case of cumulative protein curves, they were higher for the blends which were made before tempering, then for the blends made after the lots were tempered.

Calculations of the Milling Value according to Mehrotra (15) showed the same total average of $4.10 for the two systems of wheat blending and tempering before milling. That which accounts for the equality of the Milling Value of the two systems is the fact that in the system in which wheats were blended after being tempered, the yield was higher, and that in the system according to which lots were blended then tempered, ash values were generally lower and patent flour was obtained in larger amounts.

Upon examining the baked products from the first part of the experiment, where wheats were milled on the Buhler experimental mill (Plates III, IV, V) it was observed that the grain of the breads from blends where wheats were first blended then tempered were more uniform. A comparison among baked

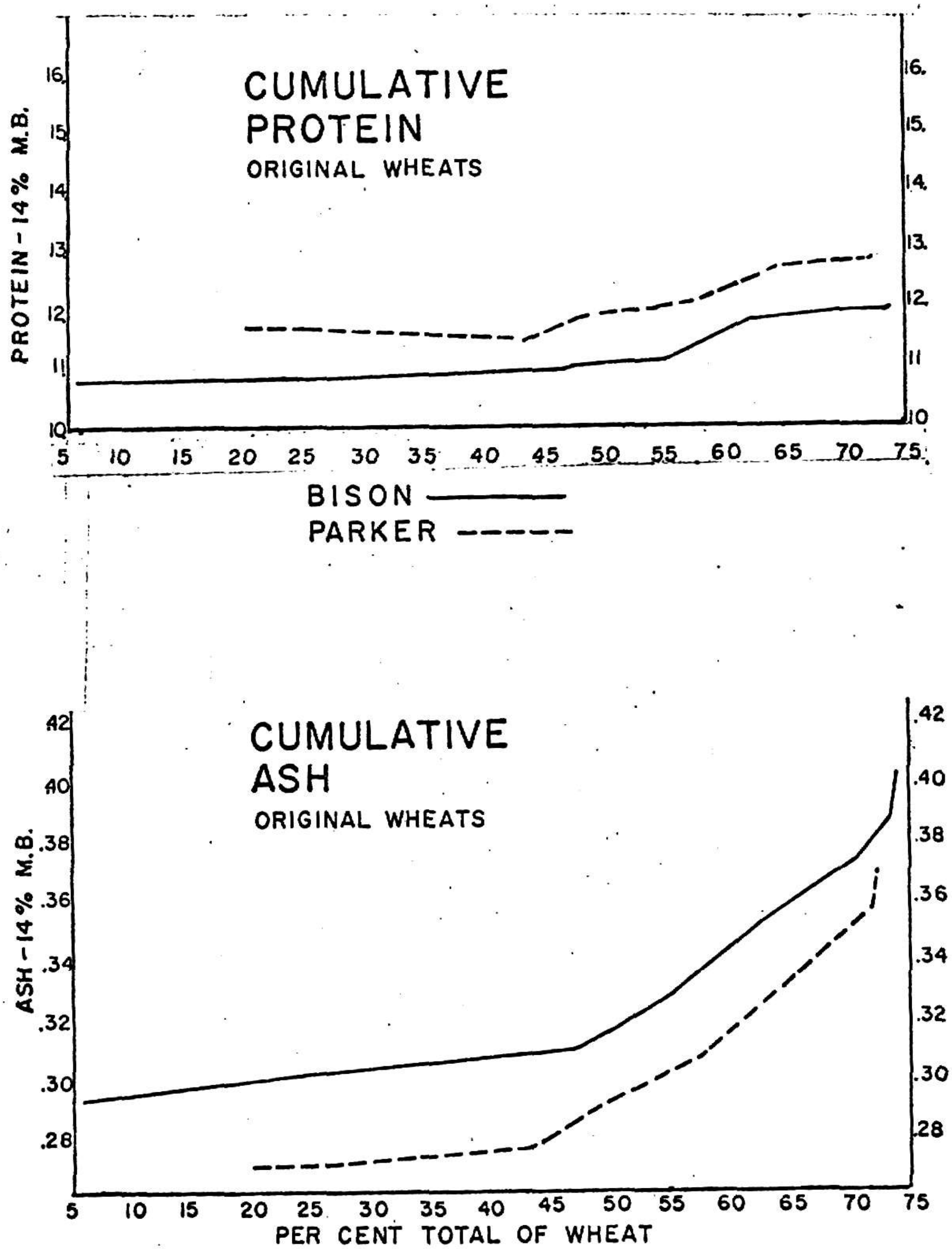


FIG. 5. CUMULATIVE ASH AND PROTEIN OF ORIGINAL WHEATS.

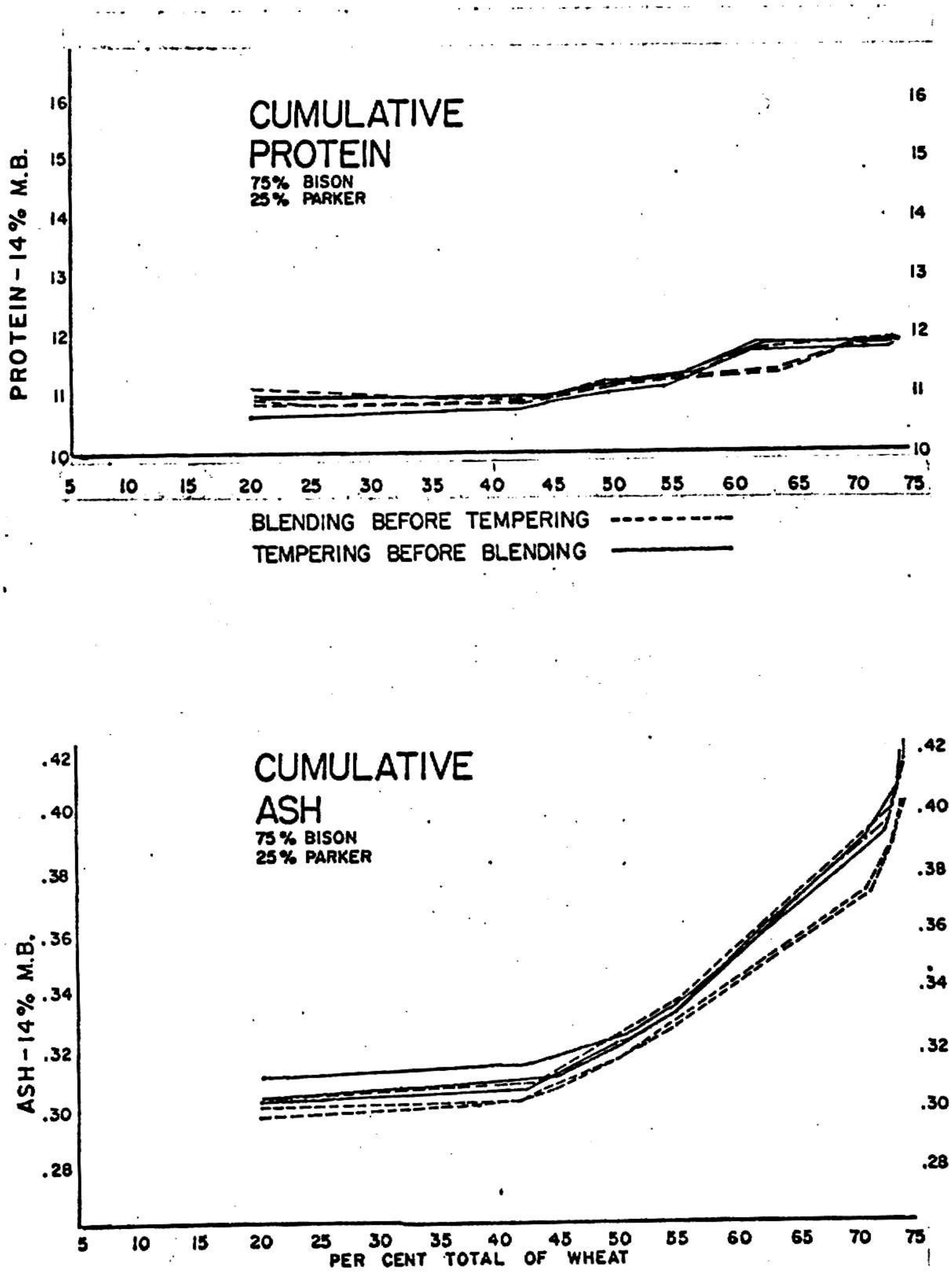


FIG. 6. CUMULATIVE ASH AND PROTEIN OF BLENDS.

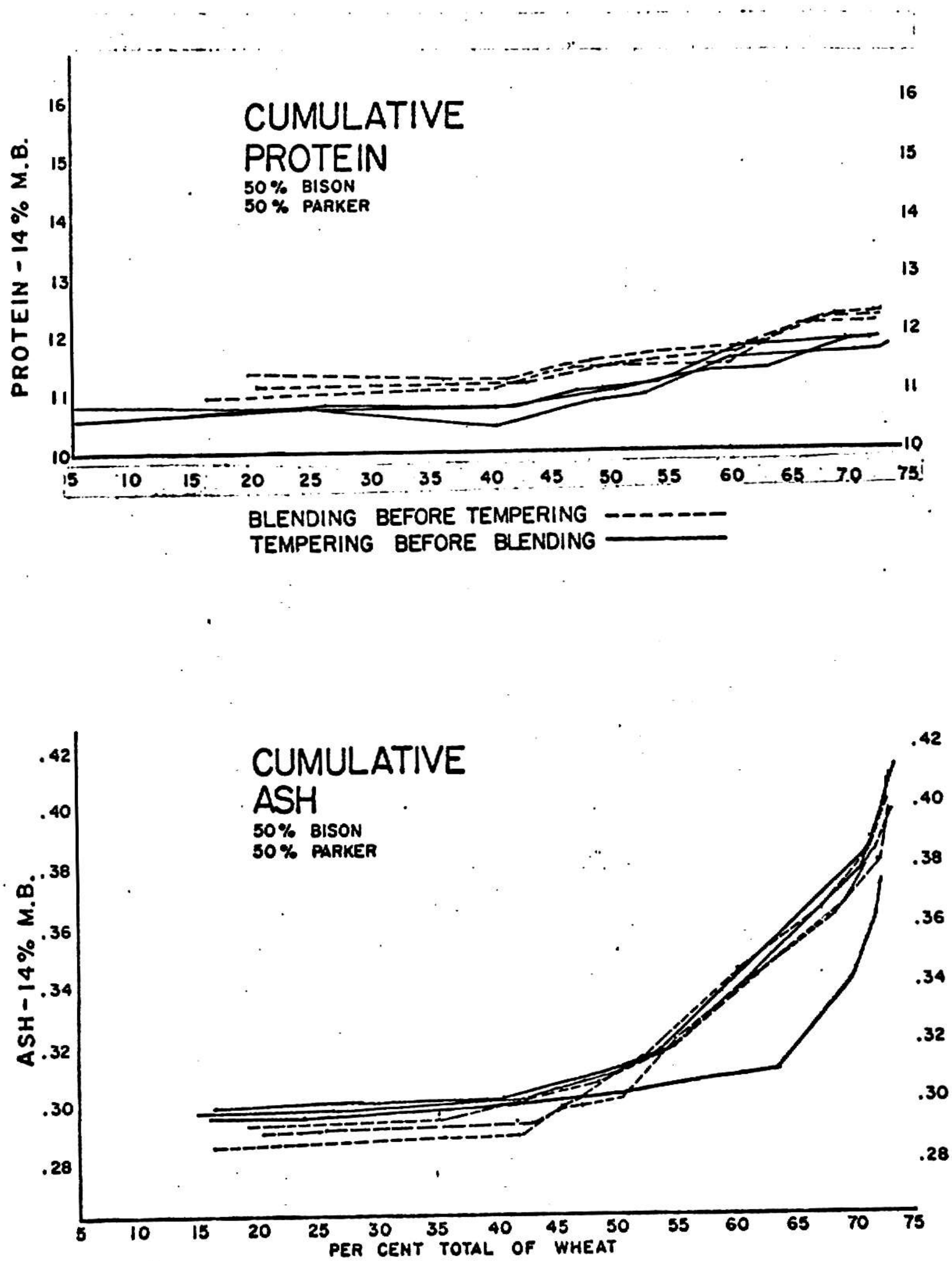
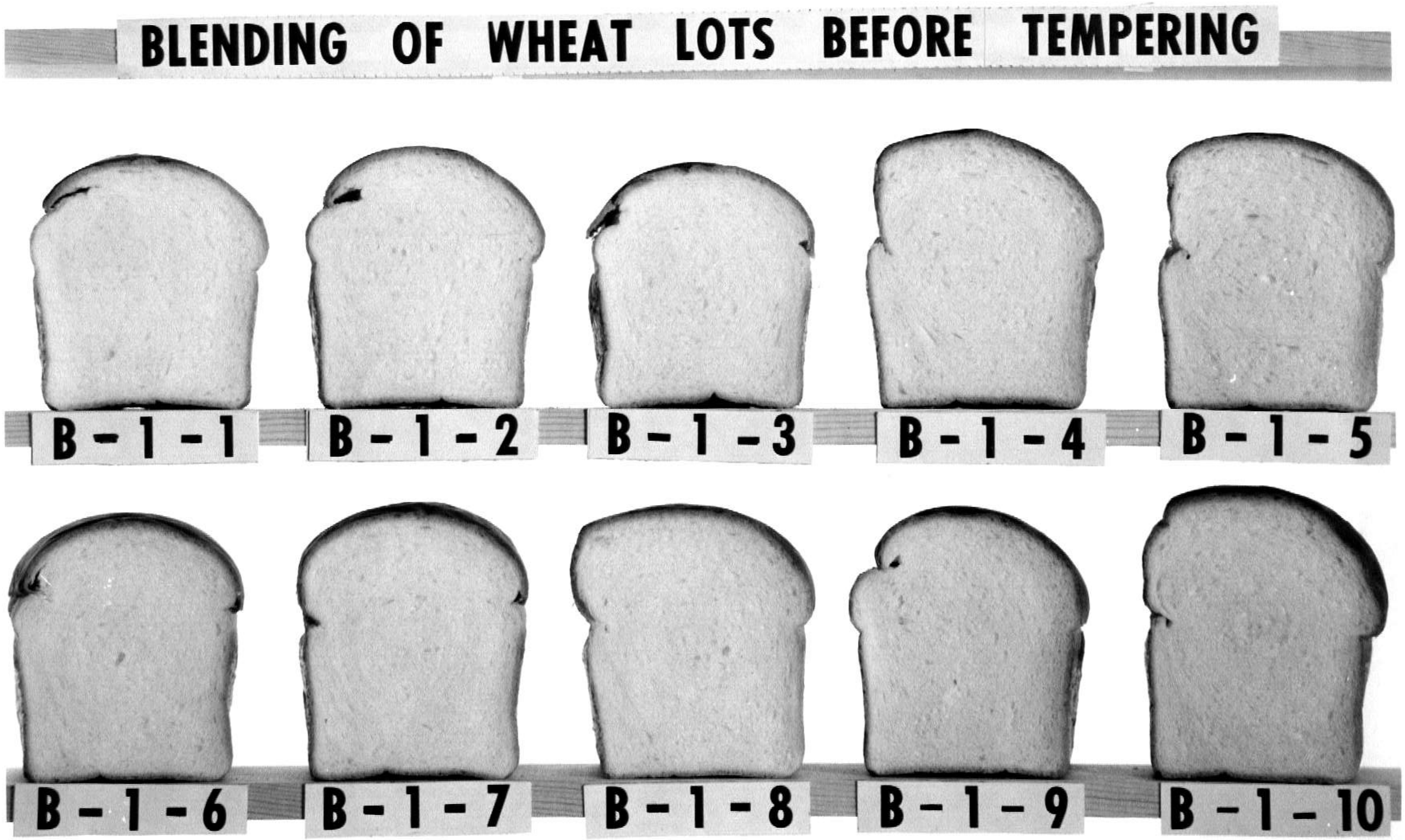


FIG. 7. CUMULATIVE ASH AND PROTEIN OF BLENDS.

EXPLANATION OF PLATE III

Photograph showing breads from blends B-1-1 to B-1-10 where lots were blended before tempering.

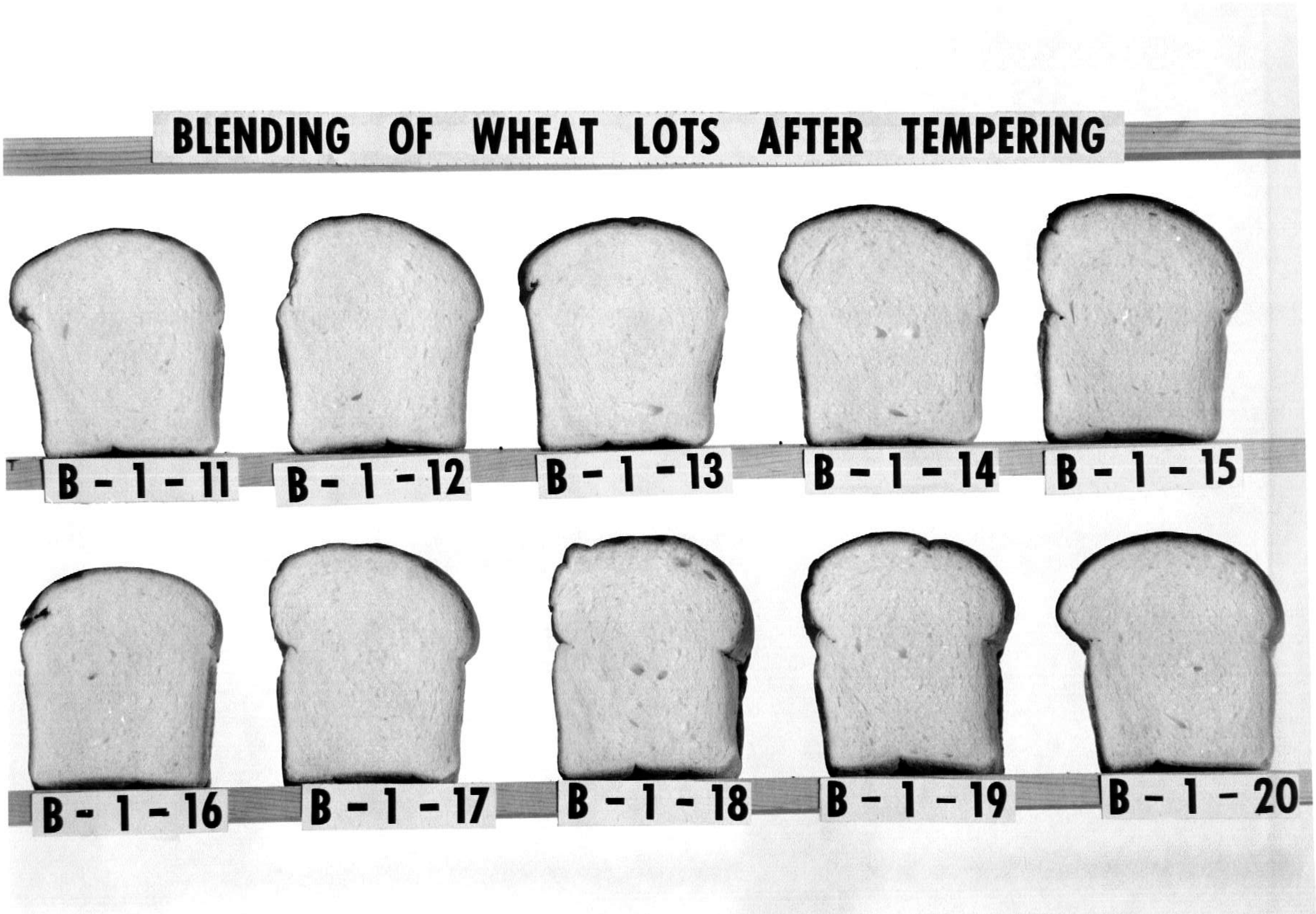
PLATE III


BLENDING OF WHEAT LOTS BEFORE TEMPERING
B - 1 - 1
B - 1 - 2
B - 1 - 3
B - 1 - 4
B - 1 - 5
B - 1 - 6
B - 1 - 7
B - 1 - 8
B - 1 - 9
B - 1 - 10

EXPLANATION OF PLATE IV

Photograph showing breads from blends B-1-11 to B-1-20 where lots were tempered before blending.

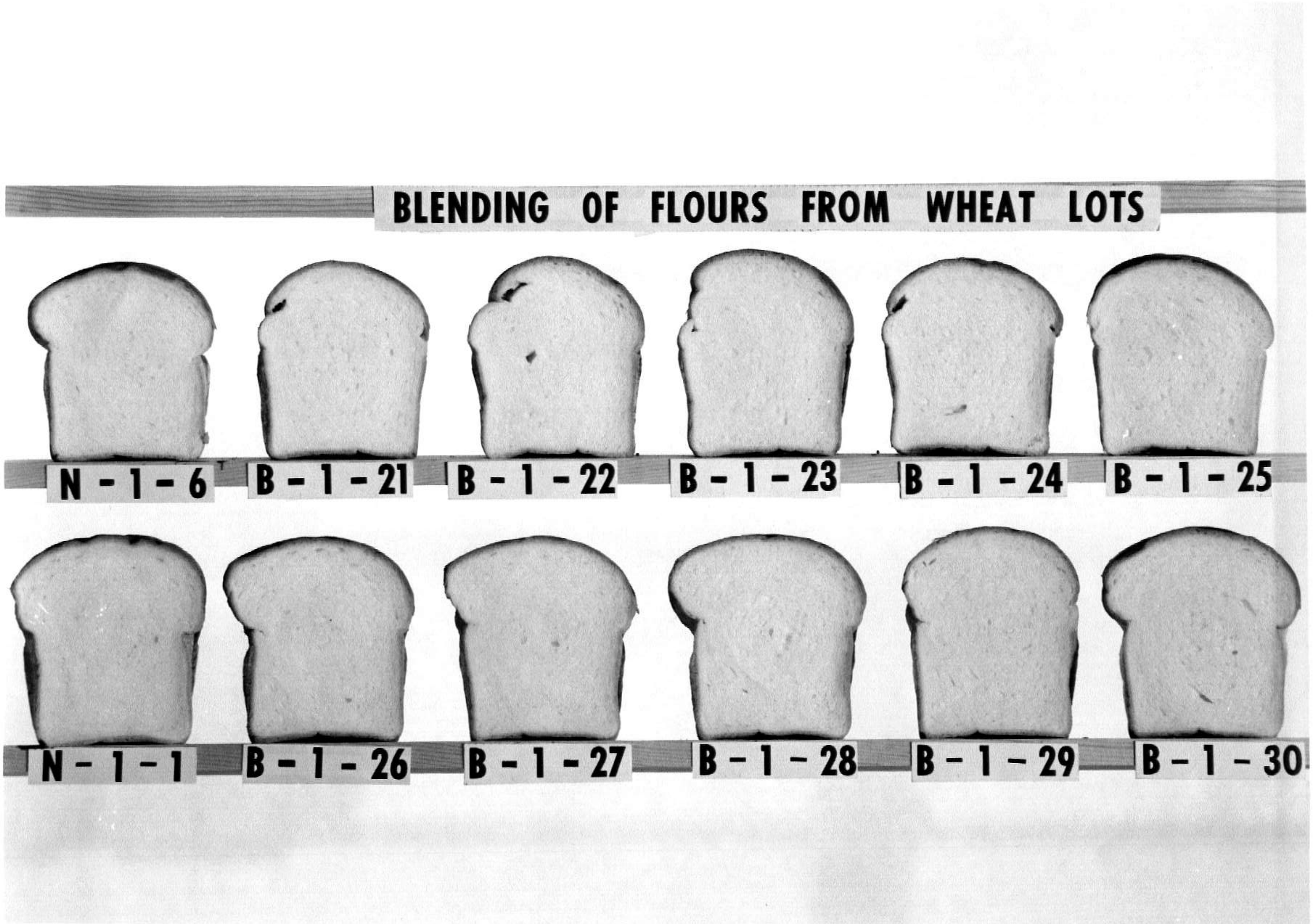
PLATE IV


BLENDING OF WHEAT LOTS AFTER TEMPERING
B - 1 - 11
B - 1 - 12
B - 1 - 13
B - 1 - 14
B - 1 - 15
B - 1 - 16
B - 1 - 17
B - 1 - 18
B - 1 - 19
B - 1 - 20

EXPLANATION OF PLATE V

Photograph showing breads from blends B-1-21 to B-1-30 where lots were milled separately on the Buhler, then blended.

PLATE V


BLENDING OF FLOURS FROM WHEAT LOTS
N - 1 - 6
B - 1 - 21
B - 1 - 22
B - 1 - 23
B - 1 - 24
B - 1 - 25
N - 1 - 1
B - 1 - 26
B - 1 - 27
B - 1 - 28
B - 1 - 29
B - 1 - 30

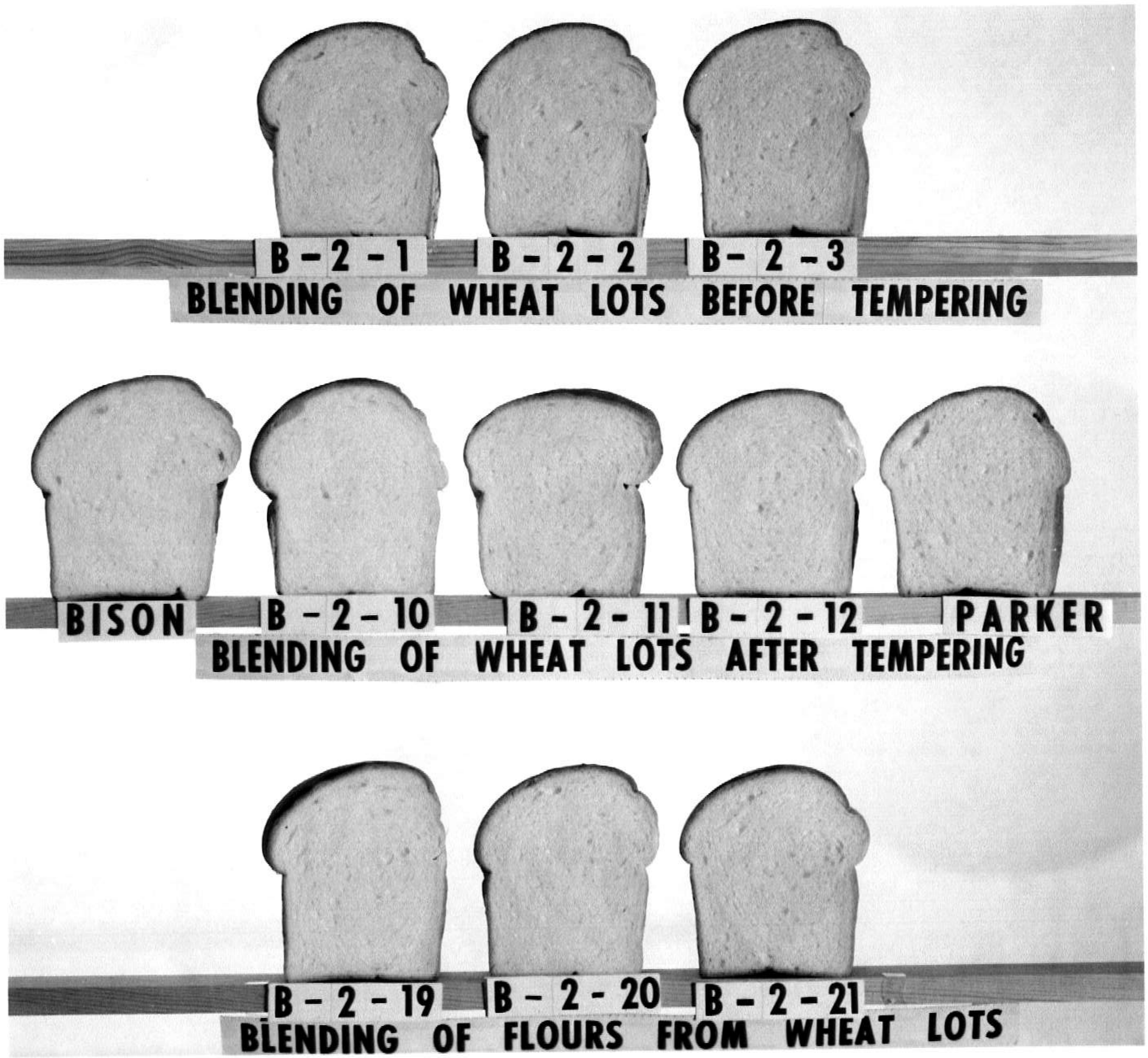
EXPLANATION OF PLATE VI

Photograph showing breads from blends milled on the Multomat in which the ratio of the lots was;

75 per cent Bison

25 per cent Parker

PLATE VI


B-2-1
B-2-2
B-2-3
BLENDING OF WHEAT LOTS BEFORE TEMPERING
BISON
B-2-10
B-2-11
B-2-12
PARKER
BLENDING OF WHEAT LOTS AFTER TEMPERING
B-2-19
B-2-20
B-2-21
BLENDING OF FLOURS FROM WHEAT LOTS

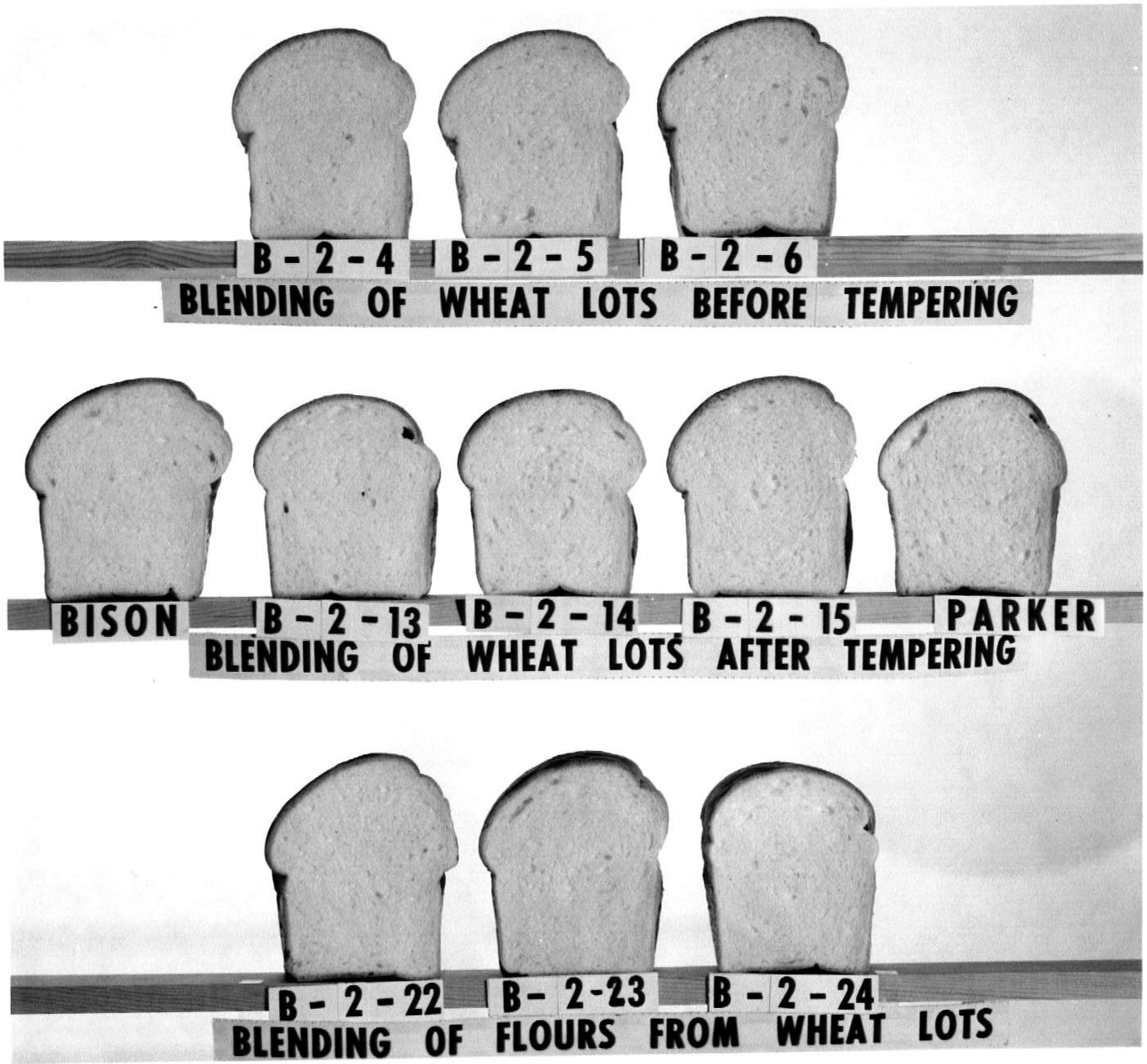
EXPLANATION OF PLATE VII

Photograph showing breads from blends milled on the Multomat in which the ratio of the lots was;

50 per cent Bison

50 per cent Parker

PLATE VII


B - 2 - 4
B - 2 - 5
B - 2 - 6
BLENDING OF WHEAT LOTS BEFORE TEMPERING
BISON
B - 2 - 13
B - 2 - 14
B - 2 - 15
PARKER
BLENDING OF WHEAT LOTS AFTER TEMPERING
B - 2 - 22
B - 2 - 23
B - 2 - 24
BLENDING OF FLOURS FROM WHEAT LOTS

loaves in the second part of the experiment (Plates VI, VII) showed that the appearance of the loaves produced from the system where wheats were blended then tempered was at least as good as that of the other two systems.

Statistical analyses

All the collected data from the tests performed on wheats, wheat blends and resulted flours, were statistically analyzed to determine whether there were any linear significant relationships between wheat tests and flour yield, and between flour tests and bread score. A two-way analysis of variance was performed to determine whether significant differences existed among the results from the systems of blending.

Table 2. Coefficients of linear correlation between wheat tests and flour yield from Buhler millings.

Wheat tests	Correlation coefficients
Dry blends; (B-1-1 to B-1-10)	
Test weight	-0.3155
1000 Kernel weight	0.2404
Pearling value	0.2789
Potential yield	0.2214
Tempered blends; (B-1-1 to B-1-20)	
Test weight	-0.3085
1000 Kernel weight	0.5957**
Pearling value	-0.8426**
Potential yield	-0.4635*
Wheat protein	0.9601**

* Significant at the 0.05 level
** Significant at the 0.01 level

Table 3. Coefficients of linear correlation between flour tests and bread score from millings on Buhler experimental mill.

Flour test	Correlations of total observations	Correlations of the blending systems	
Farinograph stability	-0.2137	B.B.T.	-0.3626
		T.B.B.	-0.1619
		B. Flours	0.4162
Farinograph MTI	0.2822	B.B.T.	0.1271
		T.B.B.	0.4403
		B. Flours	0.3048
Farinograph peak time	0.6005**	B.B.T.	0.6458*
		T.B.B.	0.6629*
		B. Flours	0.7315*
Farinograph absorption	0.7316**	B.B.T.	0.7381*
		T.B.B.	0.7525*
		B. Flours	0.8214**
FY	0.7953**	B.B.T.	0.8700**
		T.B.B.	0.7200*
		B. Flours	0.5200
Flour protein	0.8357**	B.B.T.	0.9300**
		T.B.B.	0.8327**
		B. Flours	0.9601**
	30 observations	10 observations	

* Significant at 0.05 level
** Significant at 0.01 level
B.B.T.-Blending before tempering
T.B.B.-Tempering before blending
B. Flours-Blending of lots flours

Finney and Barmore (9) found a relationship between flour protein of a wheat variety and its bread volume. This study investigated whether the relationship between flour protein and bread volume would hold for flours produced from the three systems of blending. (Table 4)

For the samples milled on the Buhler it was found that the highest correlation coefficient existed between flour protein and bread volume when flours were blended. When the lots were first blended and then tempered, the correlation was lower.

Table 4. Correlation coefficients between flour protein and bread volume.

	Blending Before Tempering	Tempering Before Blending	Blending of Flours
Buhler millings (10 obs. each)	0.7650**	0.5826	0.9080**
Multomat millings	-0.6769	-0.4174	-0.0984

* Significant at 0.05 level
** Significant at 0.01 level

No significant correlation coefficients were found between bread volume and flour proteins from blends milled on the Multomat experimental mill. The higher significant results with the Buhler experimental mill can be attributed to the mathematical model developed by Niernberger (20) with which the blends were calculated.

Extensograph studies

Munz and Brabender (18) described the importance of the extensograph as being an instrument capable of measuring changes in dough with time, and as a function of mixing, fermentation, and other treatment. Various approaches were found for the evaluation of the extensogram. Basically, all of them used the variables expressed by the curve. Munz et al. (18) distinguished doughs' response to treatment by the area and shape (F/E ratio) of the extensogram.

Merritt and Bailey (16) in 1945 when studying the effect of oxidizing treatment on the extensograph curves used the expression $\frac{(Al)(E)}{F}$; where Al is

Table 5. Correlation coefficients between extensograph values and bread score obtained from flours milled on the Buhler experimental mill (n=30)

	Blending Before Tempering	Tempering Before Blending	Blending of Flours
15 minute curves;			
Resistance (F)	0.6933	0.4981	0.7499
Extensibility (E1)	0.8255	0.8231	0.8123
Extensibility (E2)	0.6500	0.8426	0.7099
Area (A)	0.7733	0.8038	0.7828
$\frac{(A)(E1)}{(P)(F)}$	0.6252	0.8243	0.6269
$\frac{(A)(E2)}{(F)} \times 10$	0.6069	0.8335	0.6766
30 minute curves;			
Resistance (F)	0.7319	0.6198	0.7928
Extensibility (E1)	0.8075	0.8278	0.9502
Extensibility (E2)	0.8905	0.8329	0.9560
Area (A)	0.8862	0.7867	0.9207
$\frac{(A)(E1)}{(P)(F)}$	0.8254	0.8550	0.9585
$\frac{(A)(E2)}{(F)} \times 10$	0.9061	0.8182	0.9401
45 minute curves;			
Resistance (F)	0.7480	0.5358	0.7721
Extensibility (E1)	0.7698	0.7452	0.8311
Extensibility (E2)	0.8323	0.7123	0.8588
Area (A)	0.7909	0.6472	0.8338
$\frac{(A)(E1)}{(P)(F)}$	0.5733	0.7011	0.7954
$\frac{(A)(E2)}{(F)} \times 10$	0.8189	0.7050	0.8364

Correlation coefficient $r > 0.361$ is required for .05 level of significance.
Correlation coefficient $r > 0.463$ is required for .01 level of significance.

F - maximum resistance of the dough
E1- extensibility to maximum force
E2- extensibility to complete rupture

the area under the curve up to the point of maximum force. They observed that the resulting value from the expression generally decreased with time and with increased severity of oxidizing treatment. The values increased with the increase in reducing treatments. To overcome lack of correlation between $\frac{(Al)(E)}{F}$ and bread score, Merritt et al. brought up the protein content, P (15 per cent moisture basis) into the expression and values were computed from $\frac{(0.1)(P)(F)}{(Al)(El)}$ which they called the "age index".

Munz et al. (19) combined the extensograph values into an expression $\frac{(A)(E)}{F}$ x 10 which they called "Oxynumber". This value gave high correlation with bread score (Table 5) especially in the data collected from the curves made at 30 minutes resting time.

In general higher correlations were found between the extensogram evaluation data and bread score with the extensograph curves of the doughs allowed to rest 30 minutes.

A two way analysis of variance of the data collected from the extensograph curves showed significant differences only in those collected from the 30 minute curves (Table 8). In this case significantly higher resistance and larger area were found in doughs rested for 30 minutes where blending of flours was the highest, followed by the systems of blending wheats after they were tempered and before they were tempered respectively.

Two way analysis of variance

The two way analysis of variance of results from the wheat tests performed on the blends before they were milled showed significant differences between the two systems of wheat blending (Tables 6, 7).

Table 6. Two way analysis of variance of blends composed from N-1-1 and N-1-6, Buhler millings (n=20).

Wheat Test	Blending Before Tempering	Tempering Before Blending
Test weight (lb./bu.)**	56.40	58.51[a]
Wheat protein (14% M.B.)*	12.41[a]	12.15
Wheat ash (%) (14% M.B.)	1.58	1.54
1000 Kernel weight (gm.)*	31.30[a]	30.83
Pearling value (%)	71.30	71.43
Potential yield (%)	75.98	75.90
Flour yield (%)*	68.09	69.02[a]

a - significantly higher
* LSD at 5% level
** LSD at 1% level

Table 7. Two way analysis of variance of blends composed from Bison and Parker, Multomat millings (n=12).

Wheat Test	Blending Before Tempering	Tempering Before Blending
Test weight (lb./bu.)**	56.32	58.18[a]
Wheat protein (%) (14% M.B.)	13.02	13.00
1000 Kernel weight (gm.)	29.24	29.36
Flour yield (%)	73.51	73.62

a - significantly higher
* LSD at 5% level
** LSD at 1% level

This was the stage in which the blends could be compared under the same conditions. The samples milled on the Buhler experimental mill had significantly higher values for wheat protein averages and 1000 kernel weight averages, when the blends were prepared before tempering. No significant differences were found between the systems of blending when they were milled on the Multomat experimental mill. The different values of the wheat protein will be discussed further on when considering the average protein loss resulting from milling on the Buhler experimental mill. (Fig. 8).

Since wheats were blended by weight, the significant differences in test weight suggests that during the time that a prepared blend was tempered there were certain ratios in which the water was divided among the lots. These ratios depend on factors such as; initial moisture of the wheat, kernel size, structure, and protein (3). When the wheats were tempered separately the water was absorbed evenly throughout the lot. Blending the lots caused an increase in test weight of the blend. Flour yield was significantly higher in the Buhler millings when the lots were tempered separately.

A two way analysis of variance was performed on results from flour tests. The flours were produced from the three systems of blending.

In the blends milled on the Buhler experimental mill (Table 8) using the system where wheats were blended then tempered, significantly higher values were found for flour protein, farinograph peak time and farinograph valorimeter. Bread score showed significantly higher values with the system in which flours were blended. In the Multomat millings (Table 9) also significantly higher values of flour protein content and bread score were found using the system of blending wheats before tempering.

Table 8. Two way analysis of variance on results from tests performed on flours milled on the Buhler (n=30).

Flour Test	Blending Before Tempering	Tempering Before Blending	Blending of Flours
Flour protein (%) (14% M.B.)**	11.09[a]	10.95[b]	10.99[b]
Flour ash (%) (14% M.B.)	0.418	0.424	0.422
Far. absorption (%)	61.14	61.22	61.38
Far. peak time (min.)**	6.75[a]	6.20[a]	5.94[b]
Far. stability (min.)	12.30	10.70	12.65
Far. MTI (BU)	30.50	29.50	32.50
Far. valorimeter**	69.80[a]	66.60[b]	67.00[b]
FY (ml.)	45.75	44.57	46.13
Extenso. 30 min. (BU) (F)**	522.40[c]	552.50[b]	574.40[a]
Extenso. 30 min. (cm^2)(A)**	116.60[b]	125.68[ab]	132.13[a]
Bread score**	68.80[b]	68.00[b]	72.45[a]

a - significantly highest
* LSD at 5% level
** LSD at 1% level

Table 9. Two way analysis of variance on results from tests performed on flours milled on the Multomat (n=18).

Flour Test	Blending Before Tempering	Tempering Before Blending	Blending of Flours
Flour protein (%) (14% M.B.)**	11.73[a]	11.68[b]	11.95[a]
Far. peak time (min.)	6.92	6.83	5.92
Far. valorimeter	69.50	68.67	65.67
FY (ml.)	45.67	46.83	46.67
Bread score*	78.00[a]	74.25[a]	70.28[b]

a - significantly higher

* LSD at 5% level
** LSD at 1% level

Regression analysis

For a stepwise multiple regression model the following independent variables were taken; Test weight, wheat protein, pearling value, 1000 kernel weight, overs of 7 wire, overs of 9 wire, and overs of 12 wire. The dependent variable was flour yield. All these tests were performed on the tempered wheat before it was milled on the Buhler experimental mill. R-Square for the regression equation was found to be 0.9671 (20 observations). The most significant independent variable in the model was wheat protein.

A regression analysis performed on flour milled on the Buhler experimental mill included included the following independent variables; Flour protein, bread volume, farinograph stability, farinograph absorption, farinograph peak time, M.T.I., "FY" sedimentation, ash content, and amylograph value. The dependent variable of this regression equation based on flour tests, was bread score. R-Square for that regression equation was found to be 0.8984 (30 observations).

Regression analysis, with the results from dry wheat tests, of wheat blends before they were tempered showed a R-Square of 0.9326 (10 observations). In this case the independent variables were; Test weight, pearling value, 1000 kernel weight, overs of 7 wire, overs of 9 wire, overs of 12 wire, and the potential yield. The dependent variable was flour yield.

A regression analysis using results from wheat tests and flour tests as independent variables, and bread score as a dependent variable showed a R-Square of 0.8003 (20 observations). The independent variables were; Test weight of tempered wheat, "FY" sedimentation, farinograph peak time, farinograph stability, M.T.I., and flour protein. Flour protein was the most significant independent variable.

Regression analysis on the data collected in the second part of the experiment when milling on the Multomat showed the following results; Taking flour yield as the dependent variable and test weight, pearling value, 1000 kernel weight, wheat protein, overs of 7 wire, overs of 9 wire, and overs of 12 wire as the independent ones, R-Square was 0.7723.

In further analysis bread score was taken as the dependent variable. The independent variables were; flour protein, flour ash, farinograph absorption, farinograph peak time, farinograph stability, farinograph valorimeter, M.T.I., and "FY" sedimentation. R-Square found for this model was 0.4473.

The reason for the ability to make a better prediction with the Buhler models for which higher R-Squares were found, may lie in the fact that in the Multomat there are excessive reduction of the fourth and fifth midds stock which cause an undefined sharp cut point in the milling process, since the reductions cannot be evenly loaded under the experimental conditions.

Protein loss in milling

The average difference between a wheat protein and the resulted flour protein when milled on a Buhler experimental mill was determined. These average protein losses during milling were obtained for the particular Buhler experimental mill at Kansas State Milling laboratory which is in a room with stabilized temperature and relative humidity. These averages can be determined for each experimental or commercial mill with enough samples at hand.

Data of 1638 Hard Red Winter samples from Kansas Plot Tests (Environmental Series) milled on the Buhler experimental mill from 1958 through 1968 were evaluated. Only 835 samples of 57.0 lb/bu Test Weight and above were taken into consideration. The difference between wheat and flour proteins corrected to 14 per cent moisture basis were added and averaged for each wheat protein (Fig. 8).

Generally it can be said that as wheat protein increases in the sample, "protein loss" resulting from milling on the Buhler will also increase.

When comparing the expected to the resulting average proteins of flour produced in each system of blending (Table 10) it was observed that the deviations, or errors between the values were in the magnitude of 1.6 per cent.

The results from the protein recovery analysis imply that the significant differences in flour protein between the systems used were not caused by the milling process on the Buhler experimental mill.

FIG. 8. AVERAGE PROTEIN DIFFERENCE BETWEEN WHEAT AND THEIR FLOURS MILLED ON BUHLER EXPERIMENTAL MILL 1959-1968 WHEAT SAMPLES MINIMUM T.W. 57.0 POUNDS PER BUSHEL

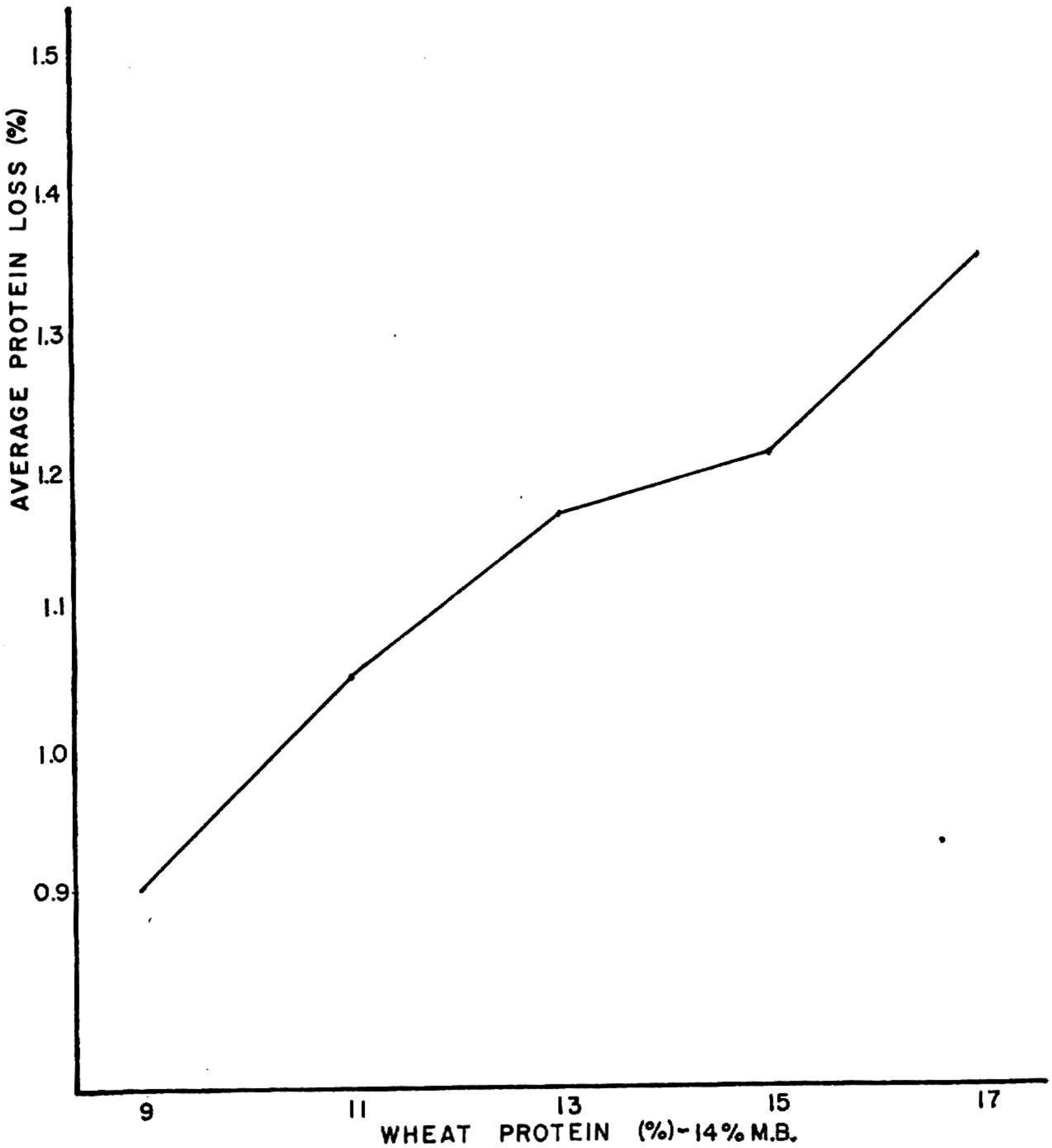


Table 10. Average protein recoveries from the Buhler and Multomat millings.

	Blending Before Tempering (%)	Tempering Before Blending (%)	Blending of Flours (%)
Average protein Buhler 14% M.B.	(wheat prot.-12.41) (expect. loss-1.13) (exp. prot.-11.28) 11.10% (10 obs.)	(wheat prot.-12.15) (expect. loss-1.12) (exp. prot.-11.03) 10.95% (10 obs.)	10.99% (10 obs.)
Average protein Multomat 14% M.B.	12.08% (6 obs.)	11.85% (6 obs.)	11.94% (6 obs.)

The reason for the differences is in the method of preparing the wheats for the milling process since this was the only stage where the handling of the blends differed.

SUMMARY AND CONCLUSIONS

It was the purpose of this investigation to study the effect of three systems of blending wheat lots under experimental conditions. The systems were; blending wheats before they were tempered, blending wheats after they were tempered and blending of flours. The wheats were tempered to the milling moisture of the experimental mills which was 16.0 per cent.

The series of experiments were performed, one using the Buhler experimental mill and the other using the Miag Multomat experimental mill. In each series two different varieties of Hard Red Winter wheats were used to make up the blends.

Drawing conclusions from the observations and statistical analysis it was established that blending of flours from the wheat lots gave the best results in most cases. These results may have been obtained because the blended flours were milled separately. Using this procedure it is possible to derive the best flour characteristics from a wheat lot. When taking into consideration wheat tests, flour tests and monetary evaluation of the flours, it was found that blending lots before they were tempered would give better or at least as good results as tempering them separately and then blending.

Flour protein content was one of the variables that showed significant difference among the systems of blending. Analysis of the protein loss during milling, from the samples milled on the Buhler experimental mill, showed that the difference in protein was not dependent on the milling process, but on the system in which the blends were prepared.

At this stage, considering the requirements for extra power, bins and needs of adjustments of equipment in using the systems of blending of wheats after they were tempered, and especially in blending of flours to meet specifications, it can be concluded that under the conditions under which the experiments were performed blending of wheats before they were tempered was found to be the most preferable system.

SUGGESTIONS FOR FUTURE WORK

Possibilities for future work may include the continuation of the research with emphasis on the following:

1) Comparison of the results obtained in the present study with results that might be obtained using the threc systems of blending on a commercial scale mill.

2) Under the experimental condition there was no place for the tempering of wheats to their optimal milling moisture. In a test on a commercial mill, this method of tempering should be taken into consideration.

3) In the field of flour testing, in order to construct a mathematical model, there is still a need for an objective evaluation and recording of the stages of dough fermentation and of the baking process. The Maturograph which indicates the optimum fermentation power, and the Oven-Rise Recorder which indicates the volume of the resulting bread while it is being baked under standardized conditions, are two instruments that may be used for that purpose. (Description of the instruments is in the Appendix.)

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation and gratitude to Professor Arlin B. Ward for his advice, guidance and suggestions during the research and in the preparation of the manuscript.

To Dr. William J. Hoover, head of the Department of Grain Science and Industry, I wish to express my gratitude for providing the facilities and materials that were needed for the project.

I express my sincere appreciation to Professor Eugene P. Farrell for being on my graduate committee and giving advice and guidance in the planning of the project.

Acknowledgement is given to my graduate committee member, Dr. Leonard W. Schruben, and also to Dr. William A. Faught, Chief, Fibers and Grains Branch, Marketing Economics Division, Economic Research Service, for their interest in the research study. The research conducted for this thesis was supported in part by funds provided under the "Systems Analysis of Wheat Quality" project financed as a joint endeavor of the Economic Research Service, U.S. Dept. of Agriculture, and the Kansas Agricultural Experiment Station, Kansas State University.

I wish to take this opportunity to express my appreciation to Dr. Floyd F. Niernberger for his helpful suggestions.

Finally, but not least I extend my gratitude to the staff of the Department for their assistance during the project.

REFERENCES CITED

(1) American Association of Cereal Chemists, Inc. 1962. Cereal Laboratory Methods, 7th Edition, St. Paul, Minnesota.

(2) Anderson, J. E., Comparison of Experimental and Commercial Milling Results. Technical Bulletins Volume II, Association of Operative Millers. p. 114-128.

(3) Bradbury, D., J. E. Hubbard, M. M. MacMasters, and F. R. Senti. Conditioning Wheat for Milling. A survey of the literature. U. S. Department of Agriculture, Misc. Pub. No. 824; 1960.

(4) Bayfield, E. G., J. E. Anderson, W. F. Geddes, and F. C. Hilderdrand. The Effects of Mill Room Temperature and Relative Humidity on Experimental Flour Yields and Flour Properties. Cereal Chem. 20: 149-171, 1943.

(5) Cereal Millers Handbook. Volume I. Association of Operative Millers. Minnesota: Burgess Publishing Co., 1963.

(6) Eustace, W. D., and E. P. Farrell. Warm, Cold, and Cold-Soak Methods of Condition Wheat. Association of Operative Millers. Tech. Bull. p. 2722-2725, 1963.

(7) Experimental Methods. Japanese Bread Technology Research Institute. p. 22-23.

(8) Farrell, E. P., and A. B. Ward. Flow Rates and Analyses for Ash and Protein of all Streams in the Kansas State University Pilot Mill. Association of Operative Millers. Tech. Bull. p. 2842-2847, 1965.

(9) Finney, K. F., and M. A. Barmore. Loaf Volume and Protein Content of Hard Winter and Spring Wheats. Cereal Chem. 25: 291-312, 1948.

(10) Gilmore, J. W., Bulk Storage and Flour Blending. Association of Operative Millers. Tech. Bull. p. 1240-1241, 1942.

(11) Japan Institute of Baking. A Study of Hard Winter Wheat-Malt Wheat Flour Relations. Conducted by Japan Institute of Baking under contract with Wheat Associates, U.S.A., Inc., Tokyo, September 1965.

(12) Kuprits, Ya., N., Editor. Technology of Grain Processing and Provender Milling. Translated from Russian. Published for the U.S. Department of Agriculture and National Science Foundation, Washington, D.C. by the Israel Program for Scientific Translation.

(13) McCluggage, M. E., A Method for the Determination of the Milling Properties of Hard Winter Wheat and Tests of its Reliability. M. S. Thesis at Kansas State College, Manhattan, Kansas. 1940.

(14) McGregor, G., Optimization Process in a Flour Mill. Unpublished report, Department of Economics, Kansas State University. June 1964 (through Ref. 20).

(15) Mehrotra, D., Predicting Commercial Milling Results by Experimental Means. M. S. Thesis at Kansas State University, Manhattan, Kansas.

(16) Merrit, P. P., and C. H. Bailey. Preliminary Studies with the Extensograph. Cereal Chem. 22: 3720391, 1945.

(17) Miller, E. S., Bulk Storage and Blending Aid Price, Quality Control. Technical Bulletins Volume II, Association of Operative Millers. p. 406-410.

(18) Munz, E., and C. W. Brabender, Prediction of Baking Value from Measurements of Plasticity and Extensibility of dough. I. Influence of Mixing and Molding Treatments Upon Physical Dough Properties of Typical American Wheat Varieties. Cereal Chem. 17: 78-100, 1940.

(19) Munz, E., and C. W. Brabender, Extensogram as a Basis of Predicting Baking Quality and Reaction to Oxidizing Agents. Cereal Chem. 17: 313-332, 1940.

(20) Niernberger, F. F., The System Analysis Method Applied to Blending of Wheat to Meet Product Specification., Ph.D. Dissertation, Kansas State University, 1969.

(21) Pyler, E. J., Baking Science and Technology. Vol. II, Chicago: Siebel Publishing Co., 1952.

(22) Robbins, D. Ash Distribution in Flour Mill Stocks. Technical Bulletins Volume II, Association of Operative Millers.

(23) Schruben, L. W., Least Cost Wheat Mix by Computer. The Northwestern Miller, 272, No. 7 (August 1965), p. 14-16a.

(24) Scott, J. H., Flour Milling Processes, 2nd. Ed., Chapman & Hall, LTD. London, England.

(25) Seibel, W., Entwicklungen der Müllerei. Die Mühle, December 19, 1968.

(26) Seibel, W., and H. Zwingelberg. Weizensorte und Diagram der Versuchsmühle. Die Mühle, No. 45, 1960.

(27) Sherwood, R. L. and C. H. Bailey, Correlation of Ash Content of Wheat and of Flour, Cereal Chem. 5: 437-444, 1929.

(28) Shuey, W. C., Measuring the Commercial Milling Value of Wheat. A. O. M. Technical Bulletin, August 1961. p. 2620-2622.

(29) Shuey, W. C., A Wheat Sizing Technique for Predicting Flour Milling Yields. Cereal Science Today, Vol. 5: 71-72, 75, 1960.

(30) Swanson, C. O., Effects of Water on Test Weight, Flour Yield and Other Properties of Wheat. Technical Bulletins Volume II. Association of Operative Millers. p. 299-311.

(31) U. S. D. A., Official Grain Standards of the United States. Grain Division Agricultural Marketing Service, U.S. Department of Agriculture.

(32) Weber. R., Conditioning and Milling of Mixtures of Hard and Soft Wheat Without a Conditioner. Müllerei 4(51/52): 811, December 22, 1951.

(33) Wissmar, Konrad, Analytical Methods to Control Mill Efficiency. Association of Operative Millers Tech. Bull. p. 2521-2523, 1960.

APPENDIX

Maturograph and Oven-Rise Recorder

The two instruments, the Maturograph and Oven-Rise Recorder, record the behavior of the dough in the fermentation and baking process under standardized conditions. These values could be combined in a model of wheat milling and bread baking, and, in the future, could be used as feed-back in a computerized operation.

The instruments are deficient in that they do not give an indication of the internal and external characteristics of the baked product such as crumb color, grain or crust color.

The Maturograph indicates the optimum fermentation power. The curve shows the development time of the dough to its optimum, stability at the optimum and any changes in dough characteristics during the fermentation time.

The Oven-Rise Recorder instrument shows the volume of resulting bread while baked in standardized conditions. It indicates on its curve changes in volume which can be traced back to the milling of the wheat.

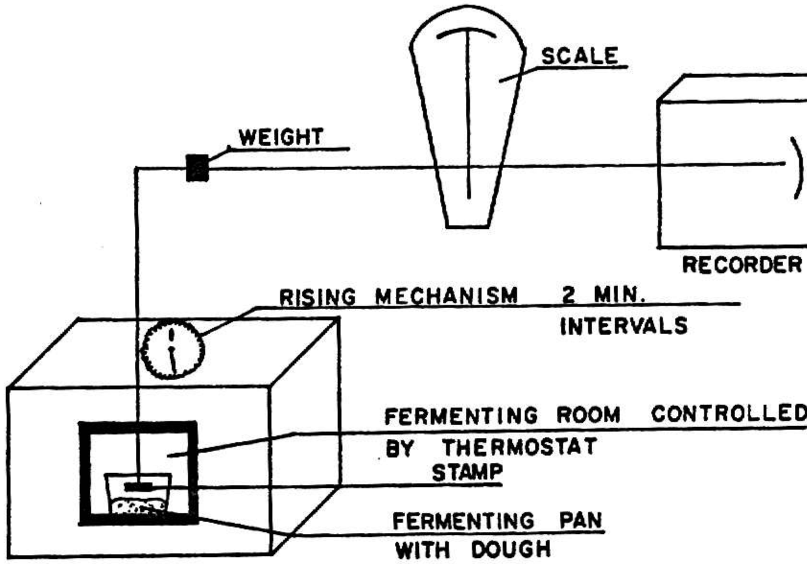
For the Maturograph flours are mixed in a Farinograph with 2.5 per cent yeast, 2 per cent salt and water to raise the curve to 450 B.U.

The Oven-Rise Recorder operates in such a manner that a 50 gr. dough is kept at 30 ^{o}C in a basket until the Maturograph curve reaches its maximum. The basket is then put into an oil bath of 30 ^{o}C, in which the temperature is raised in regulated intervals to 100 ^{o}C. Determinations are made on volume rise after; (1) End of fermentation

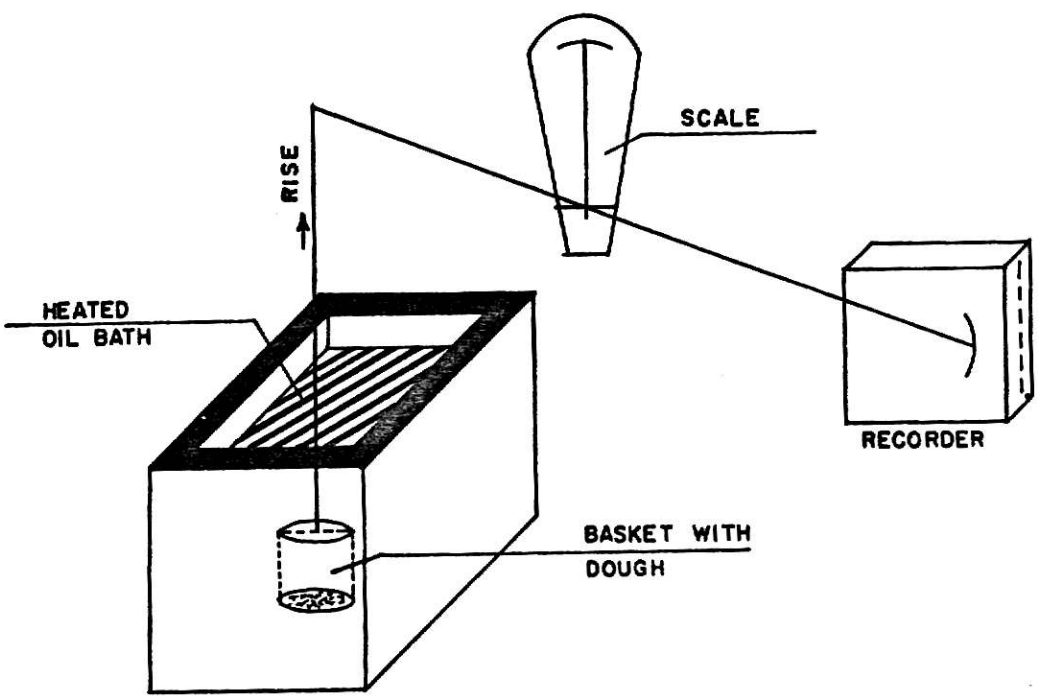
(2) After 10 min. in oil bath

(3) After 20 min. in oil bath.

Final calculations of expected bread volume are made taking into account water absorption and grams of flour to be used in the actual baking process.



MATUROGRAPH



OVEN-RISE RECORDER

FIG. 9. BRABENDER MATUROGRAPH AND OVEN-RISE RECORDER.

Table 11. Data of original wheat lots N-1-1 and N-1-6 used for Part I in the experiment.

Code	Test Weight lb/bu	1000 Kr.Wt. gm.	Pot. Yield %	Pear. Val. %	Wheat Prot.* %**	Wheat Ash* %**	TW lb/bu **	1000 Kr.Wt. gm.**	Pot. Yield %**	Pear. Val. %**	Flour Yield %
N-1-1	62.3	29.04	74.10	65.25	14.8	1.59	55.5	32.79	76.02	68.60	66.94
N-1-6	62.6	28.74	75.34	72.20	11.3	1.69	56.7	32.21	76.04	72.20	69.11

Code	Flour Prot. %*	Flour Ash %*	FY ml.	Far. Abs. %	Far. Peak Time min.	Far. Stab. min.	Far. MTI-BU	Far. Val.	Bread Volume cm^3	Bread Score
N-1-1	13.05	0.41	52.0	64.0	9.0	9.0	20	74	2662.5	77.0
N-1-6	9.75	0.42	41.5	61.0	1.5	7.5	30	56	2325.0	61.5

* 14% Moisture Basis
** Tempered Wheat Before Milling

Table 12. Wheat tests of blends milled on Buhler B-1-1 to B-1-10.

Blend	T.W lbs/ bu	1000 K.W. gm.	Pot. Yield %	Pear. Val. %	Wheat Prot.* %**	Wheat Ash* %**	T.W lb/bu **	1000 K.W. gms.**	Pot. Yield %**	Pear. Val. %**	Flour Yield %
B-1-1	62.7	29.52	75.50	71.85	11.2	1.60	57.2	30.91	76.02	72.30	69.08
B-1-2	62.7	30.44	75.52	70.45	11.3	1.60	56.7	30.49	76.00	72.75	67.40
B-1-3	62.9	29.13	75.24	70.35	11.8	1.59	56.6	31.45	76.07	72.85	68.21
B-1-4	62.6	28.99	75.26	71.85	12.0	1.59	56.3	31.20	76.04	72.00	68.48
B-1-5	62.7	29.24	75.32	70.55	12.1	1.48	56.6	31.45	76.10	70.00	68.88
B-1-6	63.0	29.85	75.36	69.35	12.8	1.59	56.2	31.52	75.78	70.95	68.33
B-1-7	63.0	28.47	75.22	69.70	13.0	1.59	56.2	30.63	75.77	71.35	66.05
B-1-8	62.6	29.05	75.26	69.35	13.3	1.60	56.0	32.26	75.82	70.90	68.32
B-1-9	62.6	29.01	75.24	67.95	13.1	1.59	56.1	31.54	75.87	69.80	68.29
B-1-10	62.3	28.99	75.04	67.40	13.5	1.59	56.1	31.60	76.07	70.10	67.89

* 14% Moisture Basis
** Tempered Wheat Before Milling

Table 13. Wheat tests of blends milled on Buhler B-1-11 to B-1-20.

Blend	Test Weight lb/bu	1000 K.Wt. gm.	Pot. Yield %	Pear. Val. %	Wheat Prot. %*	Wheat Ash %*	Flour Yield %
B-1-11	58.4	30.40	75.87	72.50	11.3	1.49	70.01
B-1-12	58.5	30.65	75.92	72.45	11.3	1.48	69.32
B-1-13	58.7	30.82	76.00	71.95	11.7	1.58	69.17
B-1-14	58.8	30.35	75.88	71.50	11.7	1.48	69.26
B-1-15	59.2	30.51	76.02	72.15	11.6	1.65	69.84
B-1-16	58.8	30.21	75.66	71.25	12.2	1.49	69.56
B-1-17	58.7	30.67	75.92	71.45	12.3	1.58	69.14
B-1-18	57.6	31.67	75.87	70.55	12.7	1.58	69.17
B-1-19	58.2	31.03	75.94	71.25	13.3	1.59	66.55
B-1-20	58.2	32.00	75.92	69.25	13.4	1.48	68.14

* 14% Moisture Basis
All values on tempered wheat before milling.

Table 14. Results from tests performed on flours from wheat blends B-1-1 to B-1-10.

Blend	Flour Prot. %*	Flour Ash %*	FY ml.	Far. Abs. %	Far. Arr. Time min.	Far. Stab. min.	Far. MTI BU	Far. Valor.	Bread Volume cm^3	Bread Score
B-1-1	10.0	.43	44.8	61.0	2.5	12.5	30	58	2212.5	65.0
B-1-2	10.2	.42	46.0	60.4	2.0	13.5	20	60	2225.0	61.0
B-1-3	10.4	.42	47.0	61.4	1.5	13.0	25	60	2200.0	66.0
B-1-4	10.8	.40	46.5	60.2	9.0	13.5	35	74	2350.0	68.0
B-1-5	11.0	.42	49.7	60.8	8.5	15.5	30	76	2287.5	68.5
B-1-6	11.1	.42	49.5	61.0	9.5	10.0	40	76	2200.0	65.5
B-1-7	11.5	.41	52.0	61.4	8.5	14.0	30	74	2300.0	70.5
B-1-8	11.7	.42	50.0	61.6	8.5	12.0	45	74	2375.0	73.5
B-1-9	12.0	.42	51.0	61.8	9.0	8.0	30	74	2300.0	73.0
B-1-10	12.3	.42	54.0	61.8	8.5	11.0	20	72	2462.5	77.0

* 14% Moisture Basis

Table 15. Results from tests performed on flours from blends B-1-11 to B-1-20.

Blend	Flour Prot. %*	Flour Ash %*	FY ml.	Far. Abs. %	Far. Peak Time min.	Far. Stab. min.	Far. MTI BU	Far. Valor.	Bread Volume cm^3	Bread Score
B-1-11	10.0	.42	46.0	59.6	2.0	13.0	30	58	2300.0	63.5
B-1-12	10.1	.42	46.5	60.0	2.5	12.0	20	60	2337.5	63.5
B-1-13	10.3	.42	47.5	60.4	2.0	10.5	20	58	2325.0	63.0
B-1-14	10.5	.43	48.0	62.0	7.5	9.0	20	68	2462.5	67.5
B-1-15	10.7	.43	46.5	61.4	8.5	8.0	30	70	2350.0	66.0
B-1-16	11.1	.43	49.3	61.4	8.0	11.0	40	70	2187.5	64.5
B-1-17	11.4	.44	56.0	61.6	7.5	12.0	35	70	2512.5	72.0
B-1-18	11.5	.43	50.5	61.8	8.0	11.0	30	70	2487.5	75.5
B-1-19	11.8	.42	54.0	62.0	7.5	7.5	40	70	2575.0	73.5
B-1-20	12.1	.40	47.0	62.0	8.5	13.0	30	72	2450.0	71.0

* 14% Moisture Basis

Table 16. Results from tests performed on flours from wheat blends B-1-21 to B-1-30.

Blend	Flour Prot. %*	Flour Ash %*	FY ml.	Far. Abs. %	Far. Arr. Time min.	Far. Stab. min.	Far. MTI BU	Far. Valor.	Bread Volume cm^3	Bread Score
B-1-21	9.9	.42	47.0	61.0	2.0	9.0	20	56	2337.5	63.0
B-1-22	10.1	.42	55.0	61.0	1.5	10.0	30	56	2375.0	63.0
B-1-23	10.4	.41	48.5	60.4	1.5	11.0	40	60	2437.5	70.0
B-1-24	10.7	.41	49.0	60.8	8.0	15.5	40	72	2352.5	68.5
B-1-25	10.9	.43	49.7	61.0	7.5	12.0	30	70	2412.5	71.0
B-1-26	11.1	.43	49.0	61.4	7.5	16.0	30	72	2415.0	70.5
B-1-27	11.3	.42	50.5	61.6	7.5	15.0	40	70	2480.0	77.5
B-1-28	11.6	.43	52.0	62.0	8.0	12.5	35	72	2525.0	80.0
B-1-29	11.8	.42	52.5	62.2	8.0	12.5	30	72	2525.0	80.0
B-1-30	12.1	.43	54.0	62.4	8.0	13.0	30	70	2600.0	81.0

* 14% Moisture Basis

Table 17. Results from wheat tests performed on lots and blends milled on the Multomat.+

Wheat	Test Weight lb/bu	1000 Kernel Weight Grams	Potential Yield %	Pearling Value %	Wheat Protein %*	Flour Yield %
Bison	56.2	28.86	75.62	71.80	12.7	73.76
Parker	58.6	31.90	75.72	70.05	14.3	72.16
B-2-1	55.9	28.84	75.00	67.60	12.9	73.81
B-2-2	55.8	29.33	75.40	67.75	12.8	73.71
B-2-3	55.6	29.50	75.15	68.35	12.8	74.16
B-2-4	56.01	29.61	75.45	70.20	13.1	73.42
B-2-5	57.0	29.52	75.55	71.45	13.1	73.13
B-2-6	56.7	28.65	75.42	70.50	13.4	72.82
B-2-10	57.9	28.99	75.17	72.15	12.9	74.32
B-2-11	57.8	29.37	75.15	71.10	12.6	74.21
B-2-12	58.1	29.67	75.10	71.25	12.9	73.96
B-2-13	58.4	29.05	75.35	69.55	13.1	73.00
B-2-14	58.4	29.41	75.45	70.55	13.4	73.72
B-2-15	58.5	29.67	75.45	70.15	13.1	72.50

* 14% Moisture Basis
\+ Tests Performed Before Milling

Table 18. Results from tests performed on flours produced by the Multomat.

Code	Flour Prot. %*	Flour Ash %*	FY ml.	Far. Abs. %	Far. Peak Time min.	Far. Stab. min.	Far. MTI BU	Far. Valor.	Bread Volume cm^3	Bread Score
B-2-1	11.7	.43	47.0	59.0	6.0	11.5	40	65	2583	87.5
B-2-2	11.5	.41	47.0	59.2	7.5	11.5	30	70	2556	78.5
B-2-3	11.6	.42	46.0	59.2	7.5	20.0	20	72	2502	74.0
B-2-4	11.8	.40	46.0	59.9	7.5	12.0	20	70	2538	78.0
B-2-5	11.9	.39	42.0	59.0	6.5	19.0	25	70	2370	72.0
B-2-6	11.9	.40	46.0	59.4	6.5	20.0	20	70	2452	78.0
B-2-10	11.5	.42	46.0	61.5	7.5	10.0	20	70	2492	78.5
B-2-11	11.5	.43	48.0	60.3	6.5	18.0	35	70	2651	75.5
B-2-12	11.5	.42	49.0	60.2	7.0	11.5	20	68	2384	75.5
B-2-13	11.7	.42	47.0	60.4	6.5	19.0	30	70	2324	71.0
B-2-14	12.0	.42	45.0	60.5	7.0	8.0	30	68	2361	68.5
B-2-15	11.9	.50	46.0	61.1	6.5	8.5	30	66	2483	76.5
B-2-19	11.9	.43	47.0	59.5	6.5	10.0	35	68	2461	68.5
B-2-20	12.2	.41	46.5	60.2	6.0	9.0	20	66	2433	76.0
B-2-21	11.8	.38	47.5	60.3	7.5	13.0	30	70	2488	64.7
B-2-22	11.9	.37	45.0	59.4	7.0	11.0	30	68	2520	69.0
B-2-23	12.1	.39	46.0	59.4	4.5	13.0	30	62	2483	68.5
B-2-24	11.8	.38	48.0	57.2	4.0	12.0	30	60	2411	75.0
Bison	12.0	.38	48.0	59.4	7.0	12.5	25	69	2578	74.5
Parker	12.8	.37	44.0	61.3	5.0	9.3	35	61	2488	81.5

* 14% Moisture Basis

Table 19. Data from Extensograms of flours milled on the Buhler.

	15 min. (F) BU	15 min. (El) cm	15 min. (E2) cm	15 min. Area (cm^2)	30 min. (F) BU	30 min. (El) cm	30 min. (E2) cm	30 min. Area (cm^2)	45 min. (F) BU	45 min. (El) cm	45 min. (E2) cm	45 min. Area (cm^2)
N-1-1	705	13.0	17.5	156.48	585	16.5	21.0	161.70	520	16.5	22.6	158.73
N-1-6	675	9.4	15.0	128.10	520	11.9	15.7	106.68	-	-	-	-
B-1-1	435	9.4	13.8	79.66	390	11.2	15.4	81.85	385	13.4	17.1	90.75
B-1-2	470	8.4	12.0	76.43	368	10.5	14.0	71.60	300	11.5	16.0	67.21
B-1-3	490	7.3	11.5	74.76	395	10.7	16.2	90.49	380	11.0	15.8	84.24
B-1-4	710	9.2	12.9	119.52	595	12.8	15.9	122.29	550	14.2	17.9	130.81
B-1-5	690	10.8	15.3	138.93	605	11.0	15.1	130.55	525	13.3	17.8	126.81
B-1-6	718	9.5	12.5	114.16	558	12.9	16.3	119.20	550	14.5	18.0	133.58
B-1-7	905	11.2	17.7	158.48	545	13.7	17.2	121.78	520	15.1	19.2	133.26
B-1-8	705	10.7	15.4	142.29	593	14.8	18.3	143.64	535	15.0	19.0	136.80
B-1-9	632	11.6	15.0	124.94	585	14.0	18.5	140.48	550	15.5	19.3	142.35
B-1-10	760	12.1	14.9	143.32	590	13.8	18.1	144.16	557	15.3	19.0	138.61
B-1-11	550	8.2	12.7	95.30	482	10.7	14.9	101.03	365	11.2	16.8	88.01
B-1-12	550	9.6	12.6	94.94	475	9.8	13.7	90.94	390	11.3	17.9	100.62
B-1-13	600	8.3	12.1	95.01	455	10.8	14.9	95.46	350	11.9	14.9	72.05
B-1-14	683	10.0	14.9	131.39	540	12.9	18.2	113.77	520	12.7	18.3	127.64
B-1-15	620	11.1	16.0	130.94	550	14.1	16.1	114.55	490	13.5	16.5	105.26
B-1-16	787	10.0	13.0	129.84	635	12.8	16.4	138.03	620	14.5	19.2	159.90
B-1-17	720	11.2	15.5	149.25	600	13.6	16.4	130.68	560	14.7	19.0	145.38
B-1-18	650	12.1	16.6	142.29	588	14.4	19.5	154.48	505	15.5	19.3	132.74
B-1-19	680	12.6	18.7	166.41	575	14.5	18.5	139.06	520	16.1	22.1	157.06
B-1-20	720	12.0	15.1	143.64	625	14.4	19.1	158.86	570	16.9	21.5	163.96
B-1-21	450	8.5	12.5	77.72	430	10.0	13.5	81.72	395	11.8	15.8	88.11
B-1-22	430	8.7	13.5	78.50	465	10.7	16.7	110.68	320	10.5	15.2	69.21
B-1-23	710	8.0	12.7	123.90	460	11.2	16.2	107.72	420	12.4	17.6	105.65
B-1-24	840	9.0	12.9	139.51	660	11.0	15.1	133.77	650	12.9	16.6	143.19
B-1-25	710	10.9	15.6	145.64	597	13.0	15.9	126.81	530	13.4	17.1	121.39
B-1-26	780	10.5	14.5	149.32	615	12.5	16.4	135.38	522	15.2	18.5	124.03
B-1-27	625	11.3	14.2	114.62	595	13.9	18.4	144.80	525	14.9	18.8	130.10
B-1-28	718	11.1	14.7	139.32	617	14.6	18.0	146.67	510	15.0	18.8	129.64
B-1-29	758	10.8	15.6	154.16	590	14.3	19.4	153.77	535	15.8	19.4	136.74
B-1-30	890	11.7	14.8	168.99	715	14.5	19.3	179.96	605	15.5	22.0	176.21

EVALUATION OF WHEAT TEMPERING AND BLENDING METHODS OF HARD RED WINTER WHEATS UNDER EXPERIMENTAL CONDITIONS

by

ELIESER SALMAN POSNER

B. S., Kansas State University, 1969

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

In the milling process there are two stages which are of great importance, and to a great extent still depend on a miller's judgement. These are wheat blending and wheat conditioning preparatory to the milling process.

To produce specified flour qualities the miller has to blend wheats, available in a certain amount, taking in consideration factors such as cost, wheat milling properties, and baking properties of the flours.

It was the purpose of this investigation to study the effect of three systems of blending wheat lots under experimental conditions. The systems were; blending wheats before they were tempered, blending wheats after they were tempered and blending of flours. The wheats were tempered to the milling moisture of the experimental mills which was 16.0 per cent.

Two series of experiments were performed, one using the Buhler experimental mill and the other using the Miag Multomat experimental mill. In each series two different varieties of Hard Red Winter wheats were used to make up the blends.

Drawing conclusions from the observations and statistical analysis it was established that blending of flours from wheat lots gave the best results in most cases. These results may have been obtained because the blended flours were milled separately. Using this procedure it is possible to derive the best flour characteristics from a wheat lot. When taking in consideration wheat tests, flour tests and monetary evaluation of the flours, it was found that blending lots before they were tempered would give better or at least as good results as tempering them separately and then blending.

Flour protein content was one of the variables that showed significant differences among the systems of blending. Analysis of the protein loss during milling, from the samples milled on the Buhler experimental mill, showed that the difference in protein was not dependent on the milling process, but on the system in which the blends were prepared.

At this stage, considering the requirements for extra power, bins and needs of adjustment of equipment in using the system of blending of wheats after they were tempered, and especially in blending of flours to meet specifications, it can be concluded that under the conditions under which the experiments were performed blending of wheats before they were tempered was found to be the most preferable system.