# Effect of method of tempering on single kernel moisture content and milling properties of hard red winter wheat

by

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Table of Contents

## List of tables

Page

# List of Figures

## List of Plates

## Introduction

The milling of wheat into flour involves the separation of the inner floury endosperm from the outer, cellulosic bran coat. The efficiency of such a separation, which is generally evaluated by the quality and quantity of material released, depends upon many factors such as: kernel structure, protein content, moisture content, cleaning, tempering, grinding, and bolting.

Among these latter processes preparing the wheat for milling, tempering has been given a great deal of importance.

Tempering and conditioning, which are usually used as interchangeable terms, define the process of toughening the bran and mellowing the endosperm. This is done by adding moisture to the wheat so that the endosperm separation from the bran is eased, the middlings are easily reduced to flour and the flour obtained is less contaminated by the bran.

Water addition could be accomplished under cold, warm or hot conditions. Cold conditioning or tempering is adding moisture and allowing the wheat to rest for a certain period of time at room temperature; warm conditioning is treating wheat with moisture and applying heat at temperatures below 115$^{o}$F (46$^{o}$C); and hot conditioning is the treatment of wheat with moisture and heat at temperatures above 115$^{o}$F (46$^{o}$C) (13).

Kernel structure and texture, moisture content, time, temperature, and pressure exerted on wheat during tempering are the main factors governing wheat conditioning. The variation of such factors gives

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rise to many questions by commercial mills as to what is the best tempering procedure.

As temperature increases, the rate of water penetration into the wheat kernel increases. A holding period prior to milling is necessary to allow the moisture to penetrate throughout the kernel and achieve the mellowing effect of conditioning. The use of an appropriate tempering system could help in shortening the tempering time and improving the conditioning of the wheat kernel to mill.

## Objectives

The present investigation involved samples of Kansas hard red winter wheat, Parker 76 grown in 1980, and two different tempering systems.

The two systems differ in the way of mixing and the mixing time. A Technovator mixer or "intensive mixer", which is a short mixing conveyor where the screw is replaced by blades; and a conventional tempering screw "KSU* conventional screw" which is a long mixing conveyor with lower capacity.

The wheat was tempered to 16% moisture content with samples taken from both the dry side before the wheat reaches the tempering system, and the wet side, after the wetted wheat leaves the system.

The samples were analysed for single kernel moisture content immediately after tempering, 12 hours later and 24 hours later.

The tempered wheat was held for periods of 12 hours and 24 hours

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*Kansas State University

prior to being milled. Each individual flour stream from the Miag Multomat milled samples was analyzed for moisture content, ash content, protein content, and color.

Mixing index, cumulative ash, cumulative protein and cumulative color were studied to determine the efficiency of both tempering systems.

Kernel swelling and water absorption of the wheat as measured by an air pycnometer and an electrical conductance moisture meter were also studied.

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# Review of Literature

## Factors affecting water pickup by wheat

### Kernel structure

Recently, with the increasing practice of milling mixed classes of wheat with different structures and textures, the problem of moisture preparation has become extremely complex. The improved knowledge of wheat kernel structure and texture will lead to a better understanding of the tempering mechanism.

Although there may be slight chemical changes occurring in conditioning, the main benefit is due to changes in the physical properties of the processing material (18). The bran becomes tougher and the endosperm mellow so that it promotes a more favorable separation from the bran. These physical changes involve the movement of moisture into the grain.

When wheat was immersed, Pence and Swanson (34) found that it picked up water rapidly at first (7-10% within the first 10 minutes at room temperature), then the rate of absorption decreased with time. This absorption was due to the permeability of the bran coat.

Hopf (23) and Scott (36) reported that moisture movement occurs within the wheat kernel by diffusion, with some degree of capillarity action on or near the outside surface of the grain towards the crease.

Gordon (18) stated that grains shellacked at the brush end absorbed as much water as untreated grains. Those shellacked on the germ and back end absorbed less moisture but enough to indicate considerable absorption in these regions.

This led certain authors (5, 21, 34, 41) to the conclusion that water is absorbed not only at the germ end, but also on the entire bran surface.

Hinton, J.J.C. (22) after removing successive layers from the outer surface and measuring the rate at which water was absorbed from a capillary tube in contact with wheat kernels, postulated that the testa is the most important barrier to water penetration.

Moss, R. (30) was also able to show that the major barriers to the diffusion of water into the endosperm are primarily the outer cuticle and the testa as these contain the waxy hydrophobic cutins; the depth of the outer bran layers and the degree of compression of cells might also affect the rate of water penetration. The rate of penetration will decrease with increased depth of bran layers and therefore the presence of uncompressed cells would facilitate rapid penetration in considering water penetration as obeying the laws of diffusion. Once into the endosperm the penetration of water into the outer area would depend partly on cracks along the cellular boundaries and on the number and size of the hydrophilic sub-aleurone protein masses which bind the water (30).

Milner and Shellenberger (29) noted that after moistening and drying several times, wheat kernel endosperm was fissured and cracked. The treated kernels absorbed water faster than untreated ones. This rapid moisture pickup was attributed to endosperm cracks.

Kernel texture

Fraser and Haley (17) reported that the wheat type, endosperm character, and wheat grade influence the rate of water absorption by wheat kernels.

Soft wheats absorb moisture more rapidly than hard wheats. Winter wheat varieties exhibit more rapid absorptions than spring wheat varieties. Starchy or mealy endosperm will absorb moisture more rapidly than vitreous endosperm. And low protein content wheat tends to absorb moisture more rapidly than high protein content wheat.

Zwingelberg, Eng. H (12) attributed the difference in moisture absorption and tempering between hard and soft wheat kernels to the chemical composition of the sub-aleurone layer. He stated that in hard wheat kernels, under the aleurone layer cells, there are sub-aleurone cells which are of compact structure and higher in albumen content. In soft wheat kernels the same area contains fewer sub-aleurone cells which are rich in starch material. Water, therefore, is able to penetrate this starchy area faster, and given the same tempering time, the albumen rich area in the hard wheats is insufficiently penetrated by the water. Hard wheats, therefore, require not only more moisture than soft ones, but also a more extended tempering time.

Wilson (42), in his study of compositional variations in the bran layer of wheat and their relation to milling, concluded that besides the thickness and physical nature of the bran which slow water penetration, the hydrophilic pentosans present in the bran layers tend to bind water and prevent further movement. The movement of water from the sub-aleurone layers of the endosperm into the center of the grain is probably not influenced by the pentosans.

He also stated that the starchy endosperm cell walls contain similar arabinoxylans to those found in bran and these may influence the rate of water movement into the central endosperm.

Temperature and time

Jones (27) reported that water penetration into the wheat kernels could be classified into 3 periods:

a) A rapid initial uptake due to bran hygroscopicity

b) A period of rapid decrease in moisture pickup

c) A slow and steady period of water absorption. The relationship between moisture content and time in this period is almost linear.

During the first two minutes temperature had no effect on absorption, but for the second and third periods absorption increased quickly with an increase in temperature (33).

Campell and Jones (6) stated that an increase of 12$^{o}$C between 20$^{o}$C and 43.5$^{o}$C, caused threefold increase in the rate of water movement to the check center. This increase ceases abruptly above 43.3$^{o}$C. And from 49$^{o}$C to 60$^{o}$C there is no increase in speed of moisture movement.

Fraser et al. (17) and Pence et al. (33) reported that complete saturation of a wheat kernel was reached from 2-3 hours temper at room temperature. It was also noted (7) that when an increase of 5% moisture was added to vitreous Manitoba wheat, the center of the cheek received about 1/2 its final moisture increment in about 5 hours. After 24 hours it had approximately 85% of its final moisture increment. The moisture movement in this part was not complete until after 60 hours.

Zwingelberg (12) stated that following wheat dampening, a moisture ring enveloped the berry. In damped soft wheat, moisture penetrated the peripheral endosperm layers more rapidly than is so with hard wheat.

Soft wheats are completely saturated in 10 to 12 hours compared to

20 to 24 hours or more with hard wheat.

He also concluded from the moisture ring enveloping the berry that after a short time of one to three hours, all layers high in ash content would have been dampened by water and the grain will be suitable for grinding. Finally, he carried out milling tests and concluded that the most favorable ash content was obtained after a period of 24 hours of temper time. For hard wheat the moisture ring failed to reach all the layers high in ash within the first 1-3 hours.

Kernel size

At an equal weight, larger kernels of wheat absorb moisture slower than do smaller ones (7). This difference in absorption rate was attributed to the larger absorbing surface area presented by the smaller kernels in relation to their weight.

Scouring

Kernels scoured and immersed in water for one minute showed an increased rate of water absorption (7, 8).

Campell (8) reported that the rate of moisture penetration was increased in the peripheral dorsal region of the scoured grain. The damage caused by scouring to the beard end, germ end and dorsal side was responsible for the greater part of the increased rate of moisture penetration.

Scouring, brushing or washing tends to increase the rate of moisture penetration (17).

Damping system

Water is added to wheat by different types of tempering systems such as washers, conventional screw type dampeners, and intensive mixers.

The use of intensive mixers for wheat conditioning or tempering has been gaining wide acceptance in the milling industry.

The milling industry as well as other writers claimed that this type of dampener is superior to the washers and conventional screw type dampeners because it is more sanitary, less wasteful, less space consuming and moisture addition more easily controlled. When properly used it improves the milling results as measured by yield, ash, and color of the flour.

Zwingelberg (12) carried out comparative damping experiments with damping devices refered to as:

a) Damping worm of conventional pattern with worm length of 2400 mm and 115 RPM.

b) Intensive mixer (Technovator mixer) with 1000 mm of trough length and 100 RPM.

c) Intensive damping worm with higher number of flights than Technovator mixer; 1000 mm of trough length and 1200 RPM.

Wheat samples thus tempered were left in lots of 500 to 100 kgs in bins to temper between 4 to 24 hours. To check the uniformity of damping in wheat lots and to assess the efficiency of each tempering system he ran single kernel moisture tests and determined the yield, ash content, and moisture of flours obtained on a Bubler laboratory grinder.

He concluded that the moisture content of the sample taken fluctuated, in the case of individual berries, following all processes of damping, up to around 1.5%. A longer rest or tempering period occassioned a reduction in moisture content differences of individual berries. The individual flours were independent of the type of damping process utilized when comparing flour extraction and ash content.

He reported also that when hand tested, the wetted wheat samples from different tempering systems showed certain physical differences. The tempered samples from system (c) were uniformly damp and with loss of husk and part of the germ through attrition; those from the intensive mixer (Technovator mixer) were drier and those from the conventional system (a) were of intermediate physical state.

In the same line, the germinative power of the wheat kernels was in decreasing order, i.e., wheat from the intensive damping worm (c) expressed lower germinative power than that from the Technovator mixer (b).

This later observation lead to the conclusion that mechanical action or attrition is involved when a high speed mixer is used. The mechanical action of paddles at a high RPM upon wheat kernels disloges the germ, abraids the bran coat and thus allows more water to penetrate at higher rate.

In the September, 1979 issue of diagram, a trade publication of the Buhler-Miag Company, E. Schefer (13) reviewed the use of intensive dampening and noted that ash, color, and yield of flour was improved.

In Buhler-Miag diagram 65 (9) there is a paper by C.H. Lippmen entitled, "Intensive dampening". He emphasized the fact that the intensive mixer develops a high speed mixing of water and grain and a uniform distribution of water at the surface of the wheat kernels. This better wetting enables it to add up to 5% of water in one step, something which is practically impossible with a classical dampening screw.

Rhodamine B was added to temper water and a comparison between an intensive mixer and a conventional dampening screw was carried out. It was concluded that intensive mixing improves surface distribution and gives better moisture penetration all around the kernel especially in the crease.

Fisher (16) tested a number of wheats before and after tempering with an intensive mixer and found that the range of moisture, in the wetted samples, between individual wheat kernels was statistically less than in the same wheat before wetting. When the same tests were performed, wheat wetted by a conventional conveyor gave opposite results, i.e. there was an increases spread after wetting. Samples of wheat were prepared containing different ranges of dry kernel moistures. These wheats were milled and analyzed by Ward and Wingfield on the Miag-Multomat experimental mill. The results indicated that improved milling results as measured by yield, patent percentage, ash, and profitability were obtained. They were in direct relation to the degree of uniformity in individual kernel moistures. Fisher concluded that the commercial improvements being noted are probably also due to these same phenomenon.

## Single kernel moisture content

Wheats of mixed origins were reported to have generally wider moisture content ranges than those derived from the same crop at equilibrium. This moisture content range is temporarily increased by exposure of wheat kernels to dry or damp atmosphere.

The moisture variation between wheats of different origins, of the same crop or between kernels of the same ear is due mainly to variation in kernel size, shape, consistency, and degree of maturity at harvest (31).

Oxley (31) in his study of moisture content of single kernels of wheat reported that wheat grains which have been stored in small containers have a standard deviation in water content ranging from 0.13 to 0.41%. The standard deviation of single kernel water content within a single ear was around 0.74%.

It was suggested that moisture variations of 0.5% in the mill mix may affect the milling in a closely regulated mill (3). Robinson (35) noted similar data on mixing wheat varieties of different moisture content. It was found that the moisture content of these samples remained 0.8% apart even after 63 days.

The moisture disparity between wheat kernels accounted for significant differences in grinding results (20, 37).

The use of unsuitable damping systems was also reported to accentuate individual kernel moistures and milling result differences.

The study of the water content of individual kernels was thought to provide an indirect method for investigation of the way in which individual wheat kernels exchange water between themselves and with the atmosphere. The differences in water content between dry individual kernels and wetted ones could be a significant factor in the choice of the most suitable tempering system to milling.

### Test weight and electrical conductance of wetted wheat

Test weight defines the weight of a standard volume of grain. It provides a measure of wheat grading, a guide to the potential flour yield, and because of its usefulness under certain circumstances as a guide to moisture content this test has been greatly favored by millers (34, 36).

Swanson (38) reported that factors such as water content, shape of kernel, condition of bran coat and internal air space are involved in test weight variation.

When wheat was wetted and redried, the test weight decreased then increased but it did not come back to the initial test weight. The decrease in test weight was due apparently to kernel swelling which resulted in an increase in internal air space.

Pushman (34) concluded that the decrease in test weight with increased moisture content reflects the poor packing and lower density of wetted grain.

It was reported that the friction coefficient of wheat kernels increases as the roughness and the viscosity of the mass of grain increases. When very moist the cohesive force between the grains is strongly developed and they appear to cling to each other. The attractive force is due to the surface tension of the wetting film of liquid. These changes in surface friction play a greater role in altering the test weight than do changes in grain size or density (36).

Swanson and Pence (39) stated that changes in moisture content of wheat affect test weight, protein percent at different moisture levels, and yield of flour. The higher the protein content of wheat, the greater the influence of moisture addition.

Farrell (15) used an electric moisture meter (Tag-Heppenstall) to measure the speed with which water is absorbed by wheat. He showed that the rate of absorption of water is very fast during the first 3 hours then it becomes very slow. The moisture meter used was noted to be a quick and accurate means of moisture measurement in wetted wheat; However, the amount of water added in tempering was not indicated accurately until 8 or 9 hours later.

A test conducted by Geddes and Winkler (18) showed the Tag-Heppenstall was very useful for moisture determination of ground wheat even though it was designed for use on wheat grain.

Coleman (10) reported that the Tag-Heppenstall moisture meter could not determine accurate moisture content of low moisture and low temperature grain. Grain covered with ice or snow also offers resistance to accurate testing because of the free moisture present on the surface of the grain. He found that grain moisture estimation by conductivity measurements depend upon the variation in electrical resistance with the change in moisture content of the grain. The measurement of resistance is based on Ohm's law, which states that the strength of a current equals the electromotive force divided by the resistance.

Campell, J.D. (25) reported that endosperm particles and whole grains react differently to slight moistening. The decrease in density of endosperm particles slightly moistened is fully reversible on subsequent drying. Full reversibility disappears when endosperm particles were moistened to 20%. However, in the case of whole wheat grain, the decrease in density is not fully reversible even at low moisture addition. He came up with the conclusion that this difference in behavior between whole grain and endosperm particles must be due to changes in bran structure; endosperm modification contributes substantially to the lack of reversibility in whole grain only when its moisture content is raised above 20%.

Sharp (44) found that the density of wheat grains was linearly related to moisture content between 8 and 16%, but the original value was not fully attained when the grains were dried.

Milner and Shellenberger did not detect cracks in wheat kernels after they were wetted to 20% and dried at 35$^{o}$C, but the density of the dried grain was lower, by as much as 0.03, than its original value.

## Materials and Methods

### Cleaning

Kansas hard red winter wheat, Parker 76, 1980 crop, from the Kansas State University Agronomy Farm was used.

The wheat was cleaned in the Grain Science Department cleaning house using a permanent magnet, a pneumatic lift aspirator, milling separator, dry stoner separator, gravity table, carter disc separator, entoletor scourer aspirator, and a duo-aspirator. The flow rate through the cleaning house was adjusted to seventy pounds per minute. The grain was conveyed pneumatically throughout.

### Tempering

Clean dry wheat moisture was determined by the Tag-Heppenstall moisture meter and the amount of water to bring the wheat moisture to 16% before milling was added by one of two tempering systems.

The first system used an intensive mixer model S-23 manufactured by Technovators incorporated (Plate 1 and 2a). The conveying rate and grain depth were optimized by adjusting paddle angles so that the wheat falls back on itself to obtain greater contact time. Its rated capacity was adjusted to 100 pounds/minute at 105 RPM.

The second system was a three pass screw type dampener manufactured by Mid-State Company (Plate 2b); this triple conveying screw of 25 feet length and 7 inches outside diameter was operated at 60 pounds/minute and 69 RPM.

The water rate for both systems was controlled by an automatic

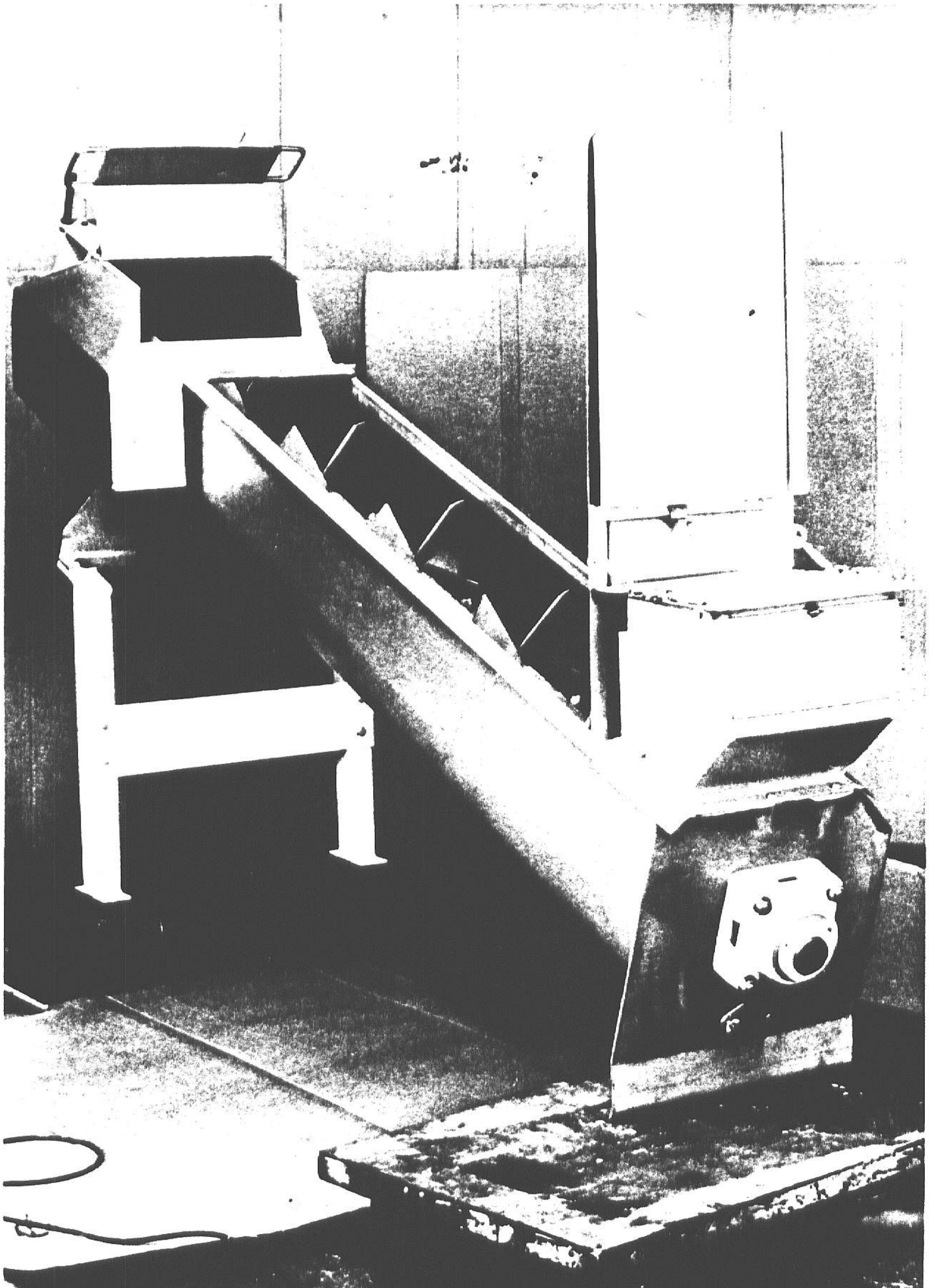
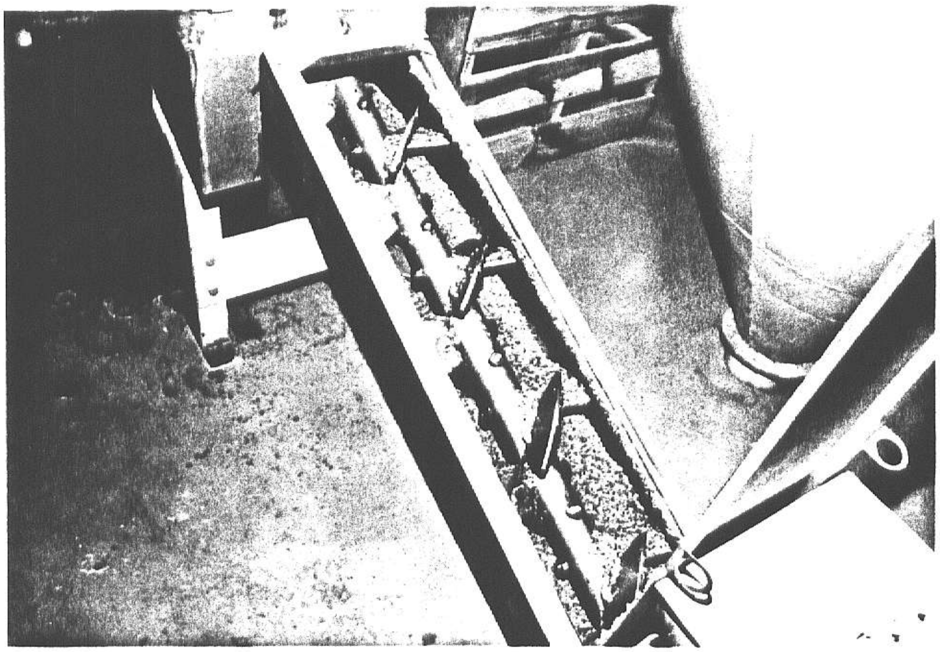


Plate 1



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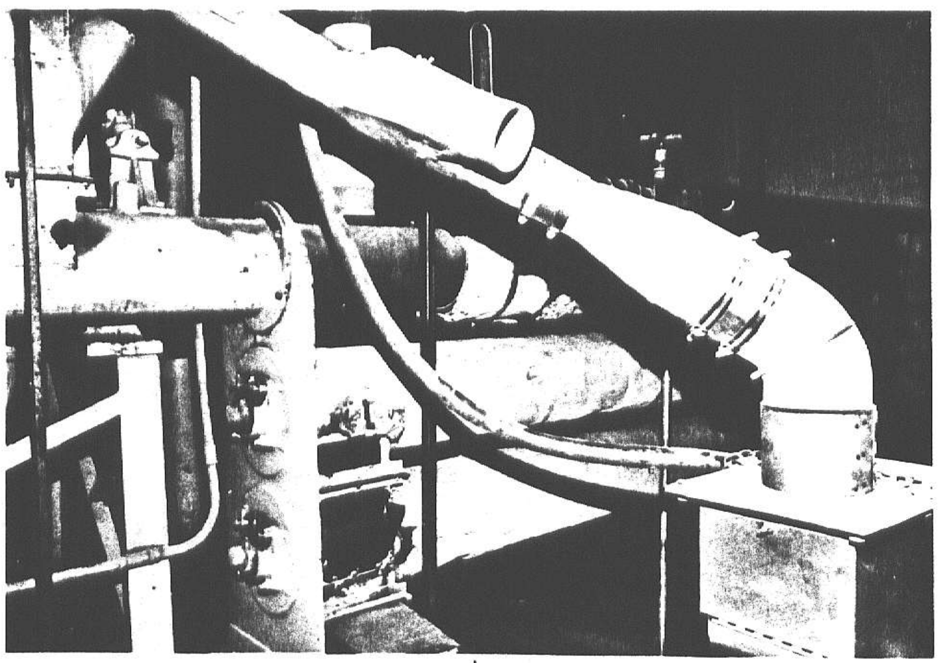

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Plate 2

water meter manufactured by the Pennwalt Company.

The wetted wheat was then kept in lots of approximately 10 bushels in stainless steel tempering bins in the cleaning house. Twelve hours later the wheat was passed through a brush machine and removed pneumatically to be milled.

## Single kernel moisture content

### Sampling procedure

Single kernel moisture content was determined for clean wheat samples taken at the inlet and outlet of the tempering system.

The conveying time of the grain from the inlet to outlet was determined to be 15 to 20 seconds in the intensive mixer and 45 seconds in the KSU conventional screw.

Two people were needed, one for the inlet and one for the outlet for concurrent sampling.

After running the system 2.5 minutes, time needed to optimize the conveying rate and the grain depth, a dry sample was taken. A wet sample was taken later by a period of time equal to the determined transit time of grain from inlet to outlet, i.e. 15 seconds for the mixer and 45 seconds for the conventional screw.

Concurrent 8 dry and 8 wet samples of approximately 250 grams each were taken at a frequency of 15 seconds for a 3 minute period in the mixer and at a frequency of 45 seconds for a 7 minute period in the conventional dampener. The samples taken were placed in plastic bags and sealed in metal cans.

Single kernel moisture determination

By means of a spatula, 20 sound kernels were transferred from each individual 250 g sample bag to a smaller plastic bag of approximately 2" x 3" dimension (Plate 3).

The 20 kernels were transferred one at a time from the small plastic bag to an analytical balance by means of tweezers.

To minimize exposure to air, the bag was pressed and the opening was closed after each single kernel transfer.

Each selected kernel was rapidly weighed to 0.0001 gram and placed sequentially on a sample grid (Plate 3). When 100 kernels were weighed, the sample grid or plate was covered with a screen and placed in a drying oven at 130$^{o}$C for 11 to 12 hours (2, 11, 26). Upon removal from the oven, the sample grid was covered quickly with aluminum foil and allowed to cool for 1 1/2 to 2 hours (Plate 4). After cooling the aluminum foil was perforated each time a dry kernel was removed and weighed. The perforation through the aluminum foil was used to prevent the remaining dried kernels from picking up moisture from the atmosphere.

If the dried kernels still under foil protection were not weighed immediately, the plate was placed in a dessicator containing activated alumina.

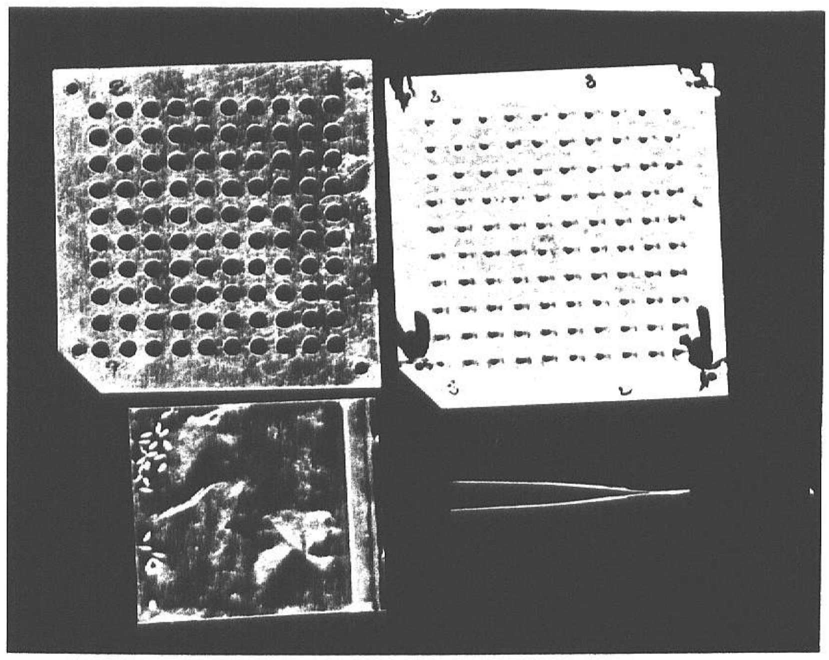
The percent moisture of each wheat kernel was calculated as follows:

$$\% \text{ moisture} = \frac{A}{B} \quad 100$$

in which:

A = moisture loss in a kernel

B = original weight of the same kernel



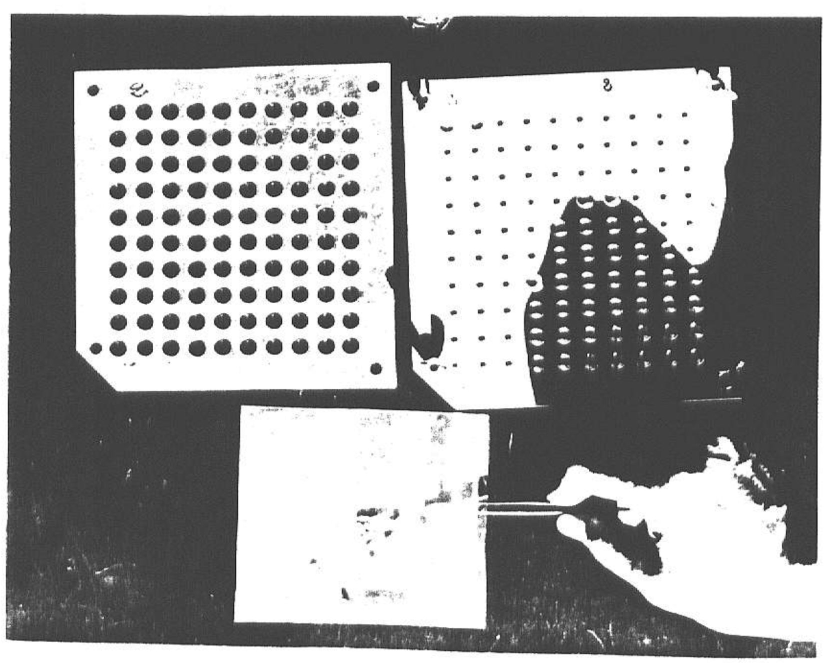
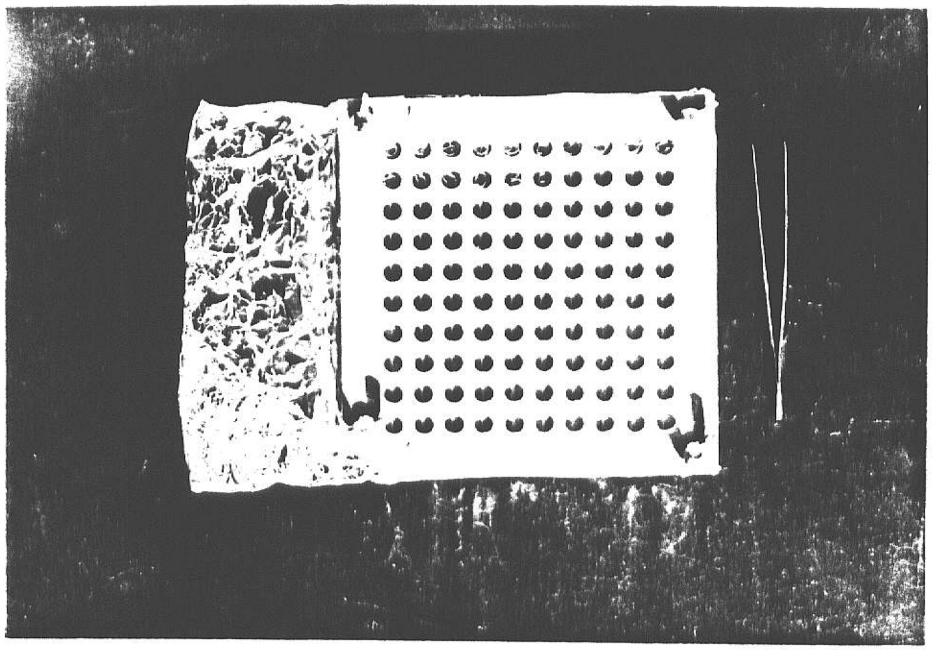


Plate 3



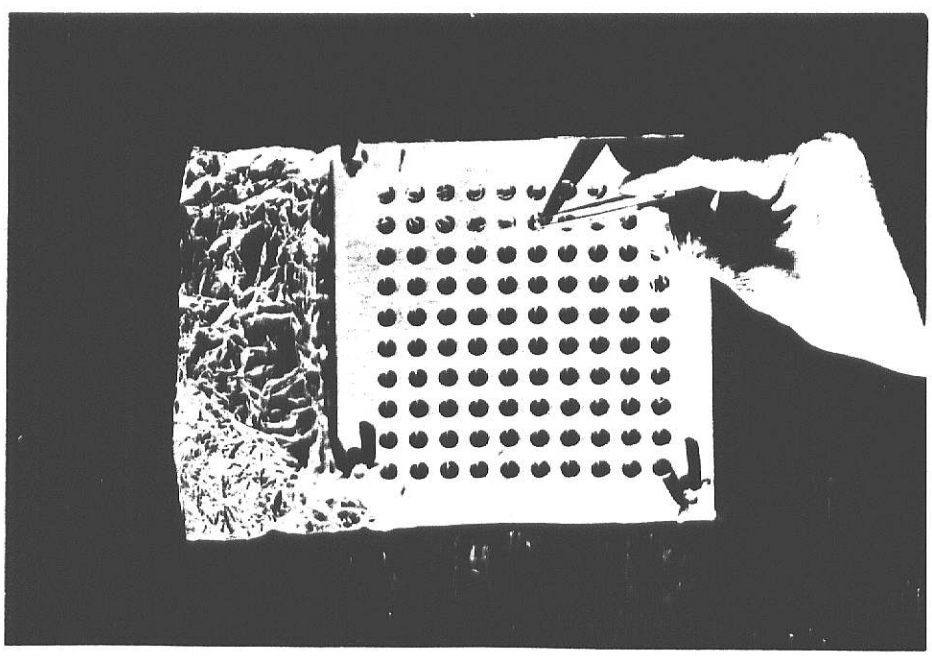


Plate 4

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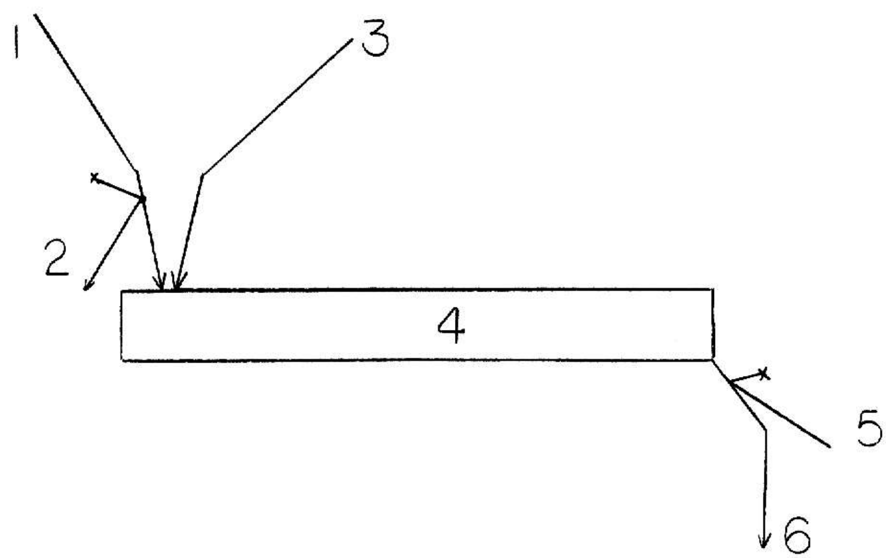
The time needed to weigh a single kernel was from 10 to 15 seconds, so that the vapor exchange between the kernel and the atmosphere was negligeable as stated by Oxley in 1948 (31). He reported that the loss or gain of water vapor was little and did not have appreciable error if the exposure period to the atmosphere did not exceed 30 to 40 seconds. When kernels are not weighed immediately, they can be left for several days in a dessicator with an appropriate dessicant without a change in weight before weighing.

The following diagram illustrates the sampling procedure used.




1. dry wheat to tempering system
2. Valve for dry wheat sampling.

   8 dry samples were taken and 20 x 8 = 160 kernels were weighed (20 kernels/sample) per replicate and per tempering system.
3. water to be added
4. Tempering system in which water is mixed with wheat
5. Valve for wet wheat sampling.

8 wet samples were taken and 20 x 8 = 160 kernels were weighed (20 kernel/sample) per replicate, per temper time and per tempering system.

6. Tempered wheat to temper bin.

The individual samples from valve 5 were sealed in a big plastic bag and kept in a sealed can for 24 hours. One-hundred sixty kernels were drawn from these samples and weighed at 12 hours temper; 160 other kernels were drawn from the same samples and weighed at 24 hours temper.

Three replicates for each tempering system were performed. A sample of 160 kernels (segregated into 8 sub samples of 20 kernels each) per replicate, per tempering system, and for each temper time was used.

The following table summarizes the sampling breakdown per replicate and per tempering system.

| | Dry wheat | Wet wheat* | immediately after tempering | After 12 hours temper | After 24 hours temper |
|---|---|---|---|---|---|
| number of sub-samples taken | 8 | 8 | | | |
| number of kernels weighed per sub-sample | 20 | | 20 | 20 | 20 |
| number of kernels weighed per sub-samples or per replicate | 160 | | 160 | 160 | 160 |

* Eight sub-samples of wet wheat were taken once and saved to sample at different temper times per replicate.

The same procedure was used during three replicates for each tempering system and the data then generated was used to compute:

a) mean kernel moisture for each 20 kernel sub-sample.

$$\overline{x} = \frac{X_1 + X_2 + X_3 + \text{-------} + X_{20}}{20}$$

in which:

$\overline{x}$ = mean

$X_i$ = each kernel moisture value (1, 2, 3, ......, 20).

b) 20 kernel standard deviation of moisture:

$$S = \frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \text{.......} + (X_{20} - \overline{X})^2}{19}$$

in which:

S = standard deviation

$\overline{X}$ = mean

$X_i$ = each kernel moisture value (1, 2, 3, ....., 20).

c) Range of moisture:

r = 6S

in which:

r = range

S = standard deviation.

d) Comparison of wet and dry samples:

$$MI = \frac{rw}{rd}$$

in which:

MI = mixing index (uniformity of moisture distribution upon kernels).

rw = range of wetted sample.

rd = range of dry sample.

Comparison of dry and wet samples was made by comparing the mixing indexes of single kernel moisture content of dry and wet wheat at immediately after tempering, at 12 and 24 hours temper time.

In addition, a statistical analysis was carried out to determine the system or temper time effects on single kernel moisture distribution.

Miag Multomat experimental mill

The tempered wheat was held for 12 and 24 hours, then milled on the Miag Multomat Laboratory mill (Plate 5a) which was equipped with a pneumatic conveying system and modified with pre-break rolls.

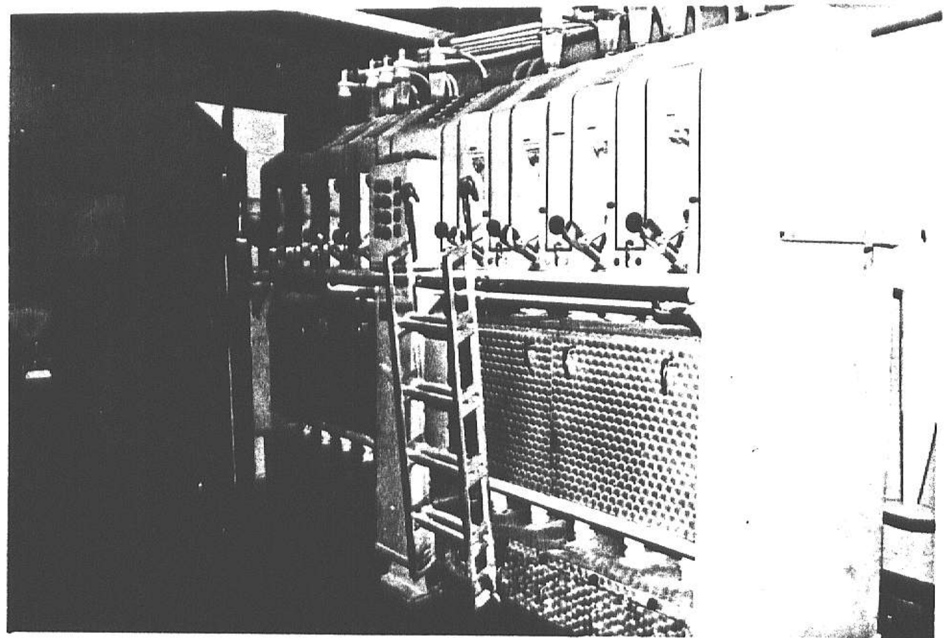
The mill was fed at 750 to 800 grams per minute and run for 45 minutes each milling. The flow consisted of three breaks, five reductions supplemented by a grader section for grading and bolting first and second break stocks, and a redust section for first midds grading and bolting (Figure 1).

The break rolls had a 2 1/2 to 1 differential and the reduction rolls and pre-break rolls a 1 1/2 to 1 differential. The break release schedule was 50% on first break, 50% on second break and a clean up on third break.

The mill was allowed to warm up for 30 minutes at the beginning of each milling test and left under load between successive milling runs.

Ten flours were produced: four break flours and six reduction flours, red dog, break and reduction shorts and bran.

All ten flours and the four feeds were weighed separately to compute the percent of each stream and the total flour yield. All the flour produced was re-sifted on a Great Western Laboratory sifter clothed with 9xx (150 micron) silk. Flour samples of 24-30 grams each were taken from each flour stream and from straight grade flour and analyzed



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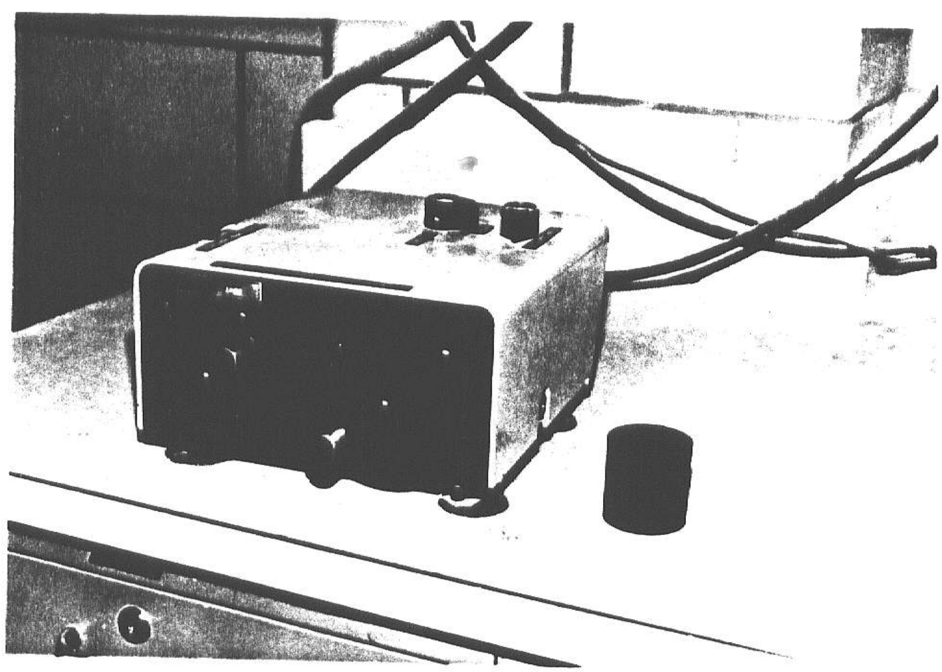

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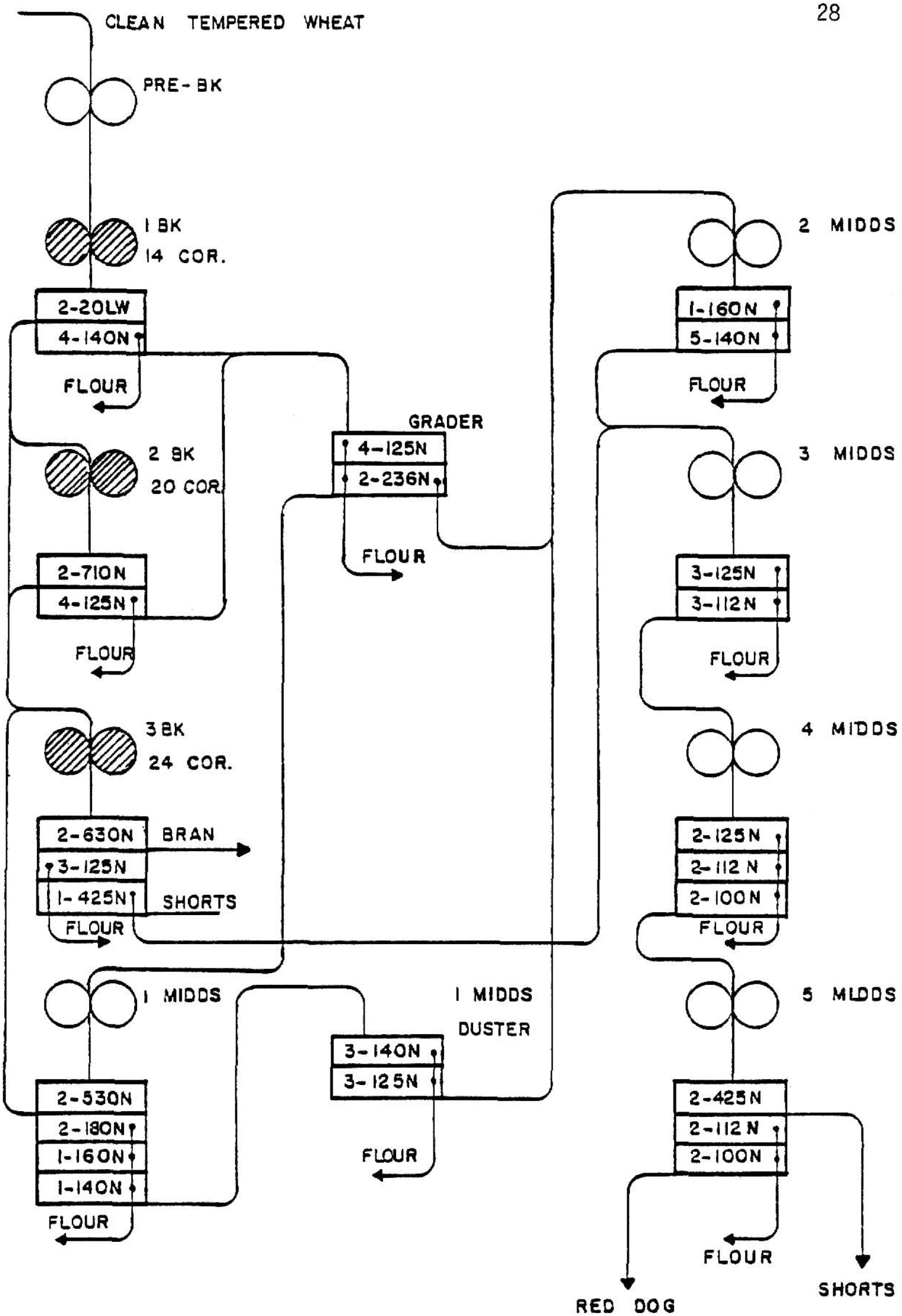
Plate 5




FLOW SHEET MIAG MULTOMAT EXPERIMENTAL MILL

FIG. 1

for moisture, ash, protein, and color.

The milling runs are summarized in the following table:

| Tempering system | milling runs/temper time 12 hours | 24 hours | date of milling |
|---|---|---|---|
| Intensive mixer | 1 | 1 | 4-26-82 |
| | 2 | 2 | 4-26-82 |
| | 3 | 3 | 5-24-82 |
| | 4 | 4 | 5-24-82 |
| | 5 | 5 | 5-24-82 |
| KSU conventional screw | 1 | 1 | 5-13-82 |
| | 2 | 2 | 5-13-82 |
| | 3 | 3 | 5-13-82 |
| | 4 | 4 | 5-17-82 |
| | 5 | 5 | 5-17-82 |
| | - | 6 | 5-17-82 |

Flour extraction, ash, protein, and color figures were reported in tables as averages per temper time and day of milling at 14% moisture basis.

Cumulative ash, protein, and color were computed and plotted as overall averages per temper time and per tempering system. Total extraction and patent flour at 0.35% ash were also computed to see the impact that any tempering system has upon milling performance.

Analysis of variance was conducted to test if there was any time or system effects on different flours characteristics.

## Methods of analysis

Test weight: Determination according to U.S.D.A. official grain standards of the U.S. Grain division Agr. Mark. Service, U.S. Department of Agriculture.

One thousand kernel weight: Determination by an electronic seed counter using 40 grams sample (as is basis).

Pearling value: outlined by 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 K.S. College, Manhattan, Kansas. 1940.

A twenty gram sample was pearled in a Strong-Scott barley pearler for 60 seconds and sifted on a 20 wire Tyler standard sieve to remove dust and breakage.

Flour moisture, ash, protein: AACC Laboratory methods (1).

Density of dry wheat: Determined with an air pycrometer according to instructions (Beckman Model 930 air comparison pycrometer).

Flour color: AACC Laboratory methods, Agtron color test of flour slurry: 14-30 (1) using disc "63" to read "0" and standard disc "85" to read "100". Readings on darker samples like "4 Midds" and 5 Midds" were obtained using standard color disc "52" for "0" setting and color disc "63" for a setting of "50". By utilizing these particular color standards, readings may be compared on the same numerical scale simply by adding 50 units to all readings obtained on the lighter mill stream samples (24).

Rate of water absorption and test weight of tempered wheat: Kansas hard red winter wheat: Parker 76 of the 1980 crop was used. The grains were cleaned in the Grai- Science Department cleaning house, then passed through a Carter Dockage Tester using the proper riddle, and aspirated by a Kice aspirator to remove all dust and fine foreign material. Water added to wheat was calculated by the following formula:

$$\frac{100 - M_1}{100 - M_2} \times W_1 = W_1 + x$$

in which:

$M_1$ = percent moisture in the original sample

$M_2$ = percent moisture in the tempered sample

$W_1$ = total weight of the original sample

X = weight of water added

The amount of water needed to bring the moisture to 16% at ambient temperature was added to wheat in a rotating drum. Ten minutes were allowed for the mixing of water to wheat.

Thirty-nine kg of wheat were tempered and placed in a plastic bag and sealed in a metal can with 24 pounds weight on top of the wheat to create the additional pressure usually exerted on wheat during tempering.

Samples were taken and density as well as moisture content were measured by the air pycnometer (Plate 5b) and Tag-Heppenstall respectively at different times: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 24 hours.

The principle of operation of the air pycnometer is based upon the measurement of the volume occupied by 14.4 grams of wheat. Knowing the weight in grams and the volume in cubic centimeters, the density of wheat would be:

$$d = \frac{m}{v} \text{ in g/cm}^3.$$

in which:

d = true density of wheat (without air space)

m = weight of wheat sample in grams

v = true volume of wheat (without air space).

The calculated test weight in pounds of wheat samples can be found as follows:

$m = d.v$ with $v = 1.25\ ft^3$

$1\ ft^3 = 0.035317$ liters

1 liter = 1000 cc

m = test weight in pound

$m = d \times 0.035317 \times 1000 \times 1.25$

C.T.W.* = d x 44.14625 LBS.

The Tag-Heppenstall electric moisture meter consists of a pair of corrugated rolls, one of which is electrified; the passage of wheat closes the circuit between the rolls and thus acts as a path for the electric current. By measuring the current (I) which has passed through the wheat going between the rolls, the resistance (R) of the wheat is determined and by Ohm's Law $I = E/R$, Voltage E, is held constant.

The resistance is inversely proportional to the moisture content. By means of conversion tables, the moisture content may be read directly.

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*C.T.W stands for the calculated test weight which is different from that obtained if the official Boerner weight per bushel apparatus was used.

## Results and Discussion

Wheat Data

Variety code No: Hard red winter wheat, Parker 76

Moisture content of dry wheat: 11.5%

U.S. bushel weight (Lbs./1.25 $ft^3$) = 63.05

1000 kernel weight (14% M.B.) = 27.63 g

Density = 1.448 g/cc

Pearling value = 76.4%

Protein % (14% M.B. and N x 5.7) = 14.47%

Ash % (14% M.B.) = 1.75

Rate of water absorption and test weight of tempered wheat.

The measurements of the electrical conductance, and the density of tempered wheat with a Tag-Heppenstall moisture meter and an air pycrometer respectively, provides an indirect method for investigating the rate at which water is absorbed in wheat, and the changes in test weight which occur during tempering.

Table 1 and Figure 2 show that the apparent moisture content of freshly tempered wheat decreases as a function of temper time. At the beginning the moisture meter indicates much higher readings corresponding to a higher moisture content than that to which the wheat was tempered (16%). At first, almost all of the water which was added was in the bran layers, it gradually penetrates the interior of the berry as temper time increases; after the first 5 hours of temper, the rate of penetration has slowed down. Water absorption seems to be almost complete at 9 hours.

Table 1. Rate of water absorption in wheat as measured by Tag-Heppenstall moisture meter.

| Hours after Temper | 0* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicated percent moisture | 11.18 | 21.10 | 19.51 | 18.25 | 17.52 | 17.03 | 16.56 | 16.49 | 16.47 | 16.27 | 16.25 | 16.17 | 16.06 | 16.05 |

*Dry wheat moisture = 11.18%

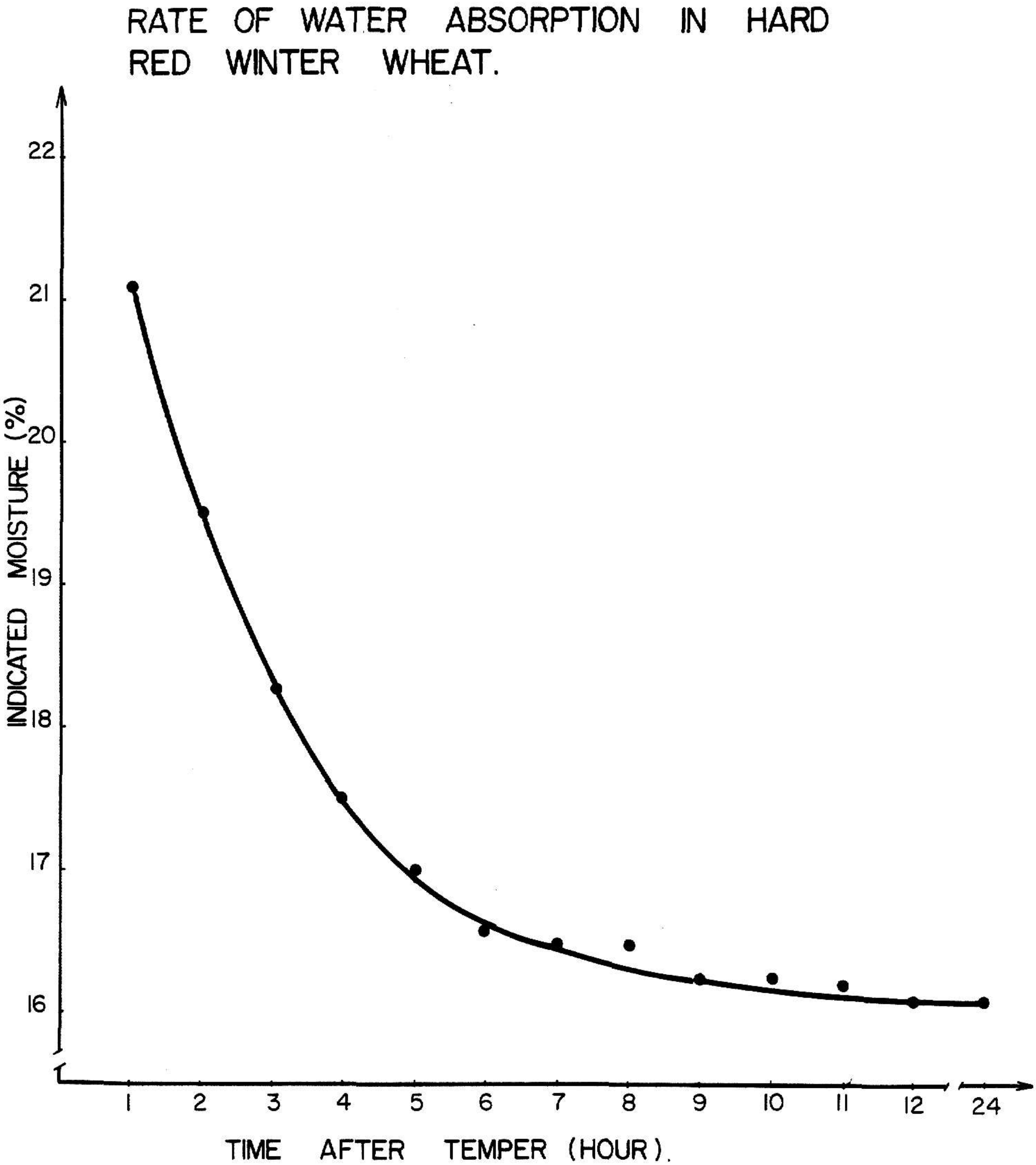

RATE OF WATER ABSORPTION IN HARD RED WINTER WHEAT.
INDICATED MOISTURE (%)
22
21
20
19
18
17
16
1
2
3
4
5
6
7
8
9
10
11
12
24
TIME AFTER TEMPER (HOUR).

FIG.2.

Further penetration is too slow to be indicated accurately by the moisture meter. The latter phase, which is long, corresponds to the penetration of some of the water already held by the outer branny layers to the interior of the wheat kernel. The apparent wheat moisture content was only .05% above the calculated 16% moisture content at 24 hours.

Table 2 and Figure 3 show that the calculated test weight of tempered wheat increased during the first 2 hours of tempering, then decreased rapidly during the following 3 hours, and then leveled off from 6 to 8 1/2 hours later. Between 9 and 12 hours, another rapid decrease in calculated test weight was noted.

This phenomena, as indicated by the curve, could have the following theoretical explanation. At room temperature, the bran layers had held almost all the water absorbed from its surrounding during the first 2 hours. This water seems to be placed in the grain cavities without causing any swelling. After 2 hours of temper time, the bulk of water absorbed seems to cause the branny layers to expand and the calculated test weight to decrease rapidly. As temper time goes on, some of the absorbed water leaves the bran to penetrate into the endosperm.

The pressure exerted by the tempered wheat causes the berrys to flatten out into the interstices of grain bulk, thus causing the calculated test weight to increase slightly between 9 and 9 1/2 hours.

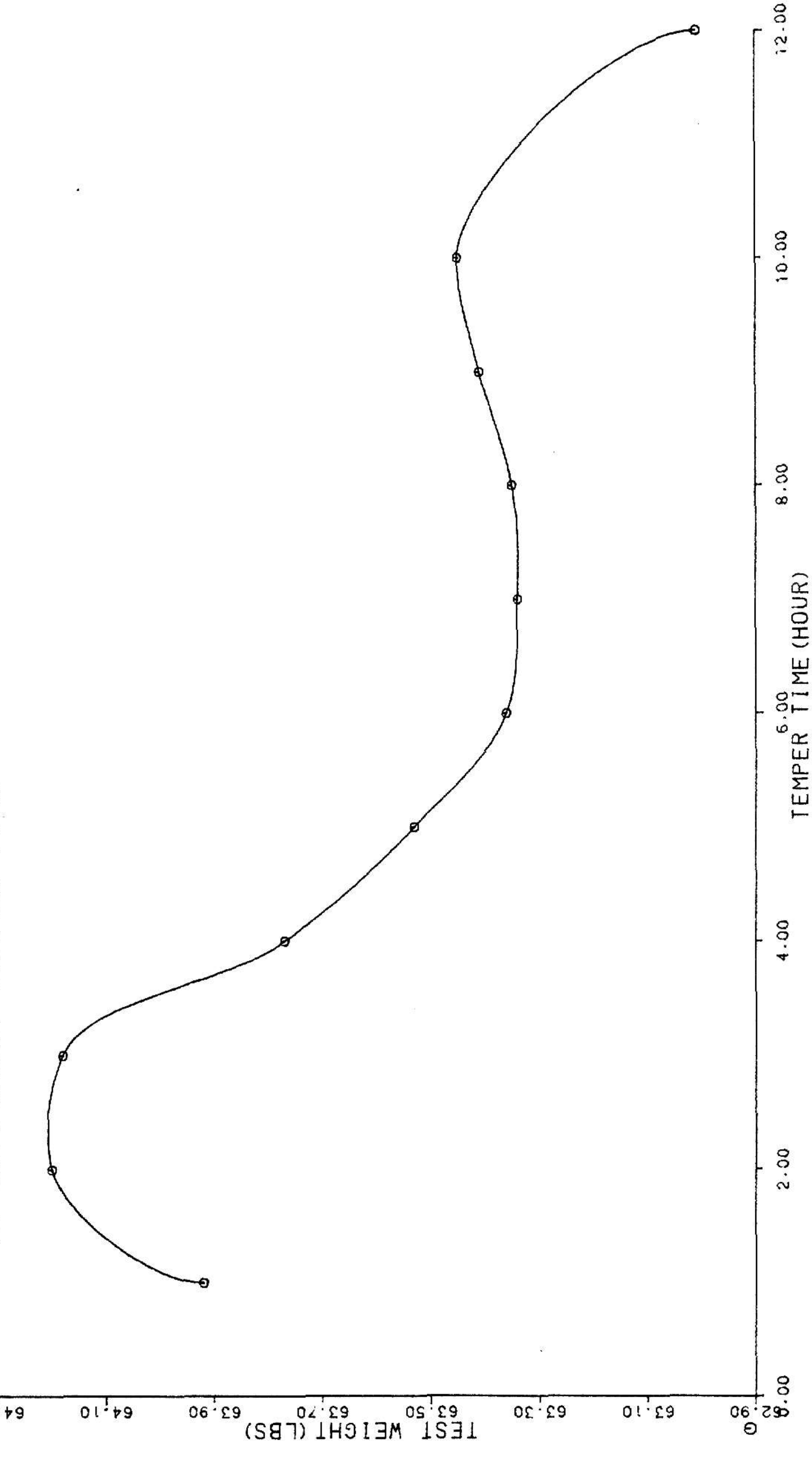
The endosperm seems to swell between 9 and 12 hours and this causes the calculated test weight to drop rapidly from 63.41 to 63.01 lbs.

The condition in which the bran and endosperm were left may be the cause of most of the decrease in the calculated test weight to 63.23 lbs at 48 hours of temper.

Table 2. Wheat swelling at room temperature as shown by density measurement at various times after damping.

| Time in Hours After Damping | Density of Wet Grains | Calculated Test Weight |
|---|---|---|
| Dry wheat | 1.448 | 63.924 |
| 1 | 1.4479 | 63.92 |
| 2 | 1.4543 | 64.20 |
| 3 | 1.4538 | 64.18 |
| 4 | 1.4445 | 63.77 |
| 5 | 1.4391 | 63.53 |
| 6 | 1.4352 | 63.36 |
| 7 | 1.4348 | 63.34 |
| 8 | 1.4350 | 63.35 |
| 9 | 1.4364 | 63.41 |
| 10 | 1.4373 | 63.45 |
| 11 | -- | -- |
| 12 | 1.4273 | 63.01 |
| 24 | 1.4266 | 62.98 |
| 36 | 1.4225 | 62.80 |
| 48 | 1.4325 | 63.24 |

FIG. 3 TEST WEIGHT OF TEMPERED WHEAT AT DIFFERENT TEMPER TIME



This is in agreement with the findings of Campell (7) who reported that the center of the cheek of vitreous Manitoba grain had received about half of its final moisture increment (of about 5%) in 5 hours and about 85% in 24 hours. But, it is in contrast to an earlier conclusion (17) that at 75$^{o}$F (24$^{o}$C) water penetrates to all parts of the grain in 2 or 3 hours.

More testing would be necessary to prove or disprove the theoretical explanations given in this thesis.

Mixing index

The basic purpose of tempering is to distribute the moisture throughout the wheat kernel so that a clean separation of the endosperm from the bran is accomplished. This will minimize the amount of bran contamination found in the flours produced.

The proper placement of the moisture in the wheat kernel depends upon many variables, such as kernel characteristics, amount of water added, temperature, and tempering system used.

A tempering system, like the intensive mixer, which has been gaining wide acceptance in the milling industry, was reported to develop rapid mixing of water and grain, add more water in one pass, and distribute it more uniformly on the surface of wheat kernels. This improved wetting was suspected to improve water absorption and reduce the moisture content disparity between individual kernels of wheat, thus improving the milling characteristics of wheat.

The standard deviation of single kernel moisture content between the dry and wetted wheat kernels was suggested as a criterion to determine kernel moisture disparity. The higher the standard deviation, the greater the moisture disparity between kernels. A ratio between standard deviation of single kernel moisture content of wet wheat and the standard deviation of dry wheat was also calculated. This ratio was referred to as the mixing index (MI). When the mixing index has a number that is smaller than one, it indicates that the standard deviation of the wet wheat is smaller than that of the dry wheat. This in turn indicates a better water distribution in the tempered wheat than in the original dry wheat, and improved milling results should be obtained.

In this investigation, two tempering systems were used: an intensive mixer and a conventional screw type dampner. Three replicates per system were performed. The corresponding mixing indexes of sub-samples per replicate and per temper time are shown in Tables 3 through 10.

The variation of moisture content in dry wheat fluctuated from one test to another. Table 11 shows that dry wheat feeding the intensive mixer had a moisture variation from 1.316 to 2.04. That variation of wheat going to the KSU conventional screw was from 2 to 2.3.

Table 6 shows that immediately after mixing in the intensive mixer, the wheat kernels had a very wide variation in moisture content between individual kernels (an exception occurred in test #3, which does not show a consistent trend), which decreased as temper time continued.

Table 10 shows that immediately after mixing the wheat in the conventional screw, there was a wide variation in single kernel moisture content. The variation observed was nearly as big as that produced by the intensive mixer (Table 6). As temper time continued, no consistent

Table 3. Mixing indexes of intensive mixer. Test #1.

| M.I. at | Sample # 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
|---|---|---|---|---|---|---|---|---|---|
| $T_o$ | 0.768 | 1.738 | 1.031 | 1.261 | 1.320 | 0.983 | 0.746 | 1.196 | 1.130 |
| $T_{12}$ | 1.014 | 1.279 | 1.072 | 1.190 | 1.290 | 0.808 | 0.806 | 1.182 | 1.080 |
| $T_{24}$ | 0.797 | 1.041 | 1.113 | 0.866 | 1.390 | 0.785 | 1.045 | 0.973 | 1.001 |

Table 4. Mixing indexes of intensive mixers. Test #2.

| M.I. at | Sample # 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
|---|---|---|---|---|---|---|---|---|---|
| $T_o$ | 0.907 | 1.009 | 1.571 | 1.386 | 1.010 | 1.781 | 0.951 | 1.211 | 1.228 |
| $T_{12}$ | 1.253 | 0.929 | 1.089 | 1.170 | 0.854 | 0.795 | 0.772 | 0.770 | 0.954 |
| $T_{24}$ | 0.963 | 0.789 | 1.009 | 0.784 | 0.789 | 0.836 | 1.056 | 1.046 | 0.909 |

Table 5. Mixing indexes of intensive mixer. Text #3.

| M.I. at | Sample # 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
|---|---|---|---|---|---|---|---|---|---|
| $T_o$ | 0.884 | 1.018 | 1.271 | 1.107 | 1.096 | 1.086 | 1.004 | 1.050 | 1.065 |
| $T_{12}$ | 1.268 | 1.055 | 1.220 | 0.842 | 1.877 | 1.233 | 0.855 | 0.969 | 1.165 |
| $T_{24}$ | 1.045 | 1.209 | 0.939 | 0.865 | 1.726 | 1.602 | 0.996 | 0.744 | 1.141 |

Table 6. Total average of mixing indexes in three tempering tests by intensive mixer.

| M.I. MEAN at | Test 1 | Test 2 | Test 3 | Total MEAN |
|---|---|---|---|---|
| $T_0$ | 1.130 | 1.228 | 1.065 | 1.141 |
| $T_{12}$ | 1.080 | 0.954 | 1.165 | 1.066 |
| $T_{24}$ | 1.001 | 0.909 | 1.141 | 1.017 |

Table 7. Mixing indexes of K.S.U. conventional screw. Test #1

| | Sample # | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M.I. at | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
| $T_o$ | 0.963 | 0.808 | 0.853 | 1.111 | 0.723 | 0.949 | 1.412 | 0.773 | 0.949 |
| $T_{12}$ | 0.826 | 1.412 | 1.406 | 1.028 | 0.992 | 0.627 | 1.329 | 1.231 | 1.106 |
| $T_{24}$ | 1.041 | 0.687 | 1.513 | 1.170 | 0.750 | 0.686 | 1.512 | 0.969 | 1.041 |

Table 8. Mixing indexes of K.S.U. conventional screw. Test #2

| | Sample # | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M.I. at | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
| $T_o$ | 1.529 | 1.974 | 1.138 | 0.747 | 2.283 | 1.466 | 1.146 | 1.198 | 1.435 |
| $T_{12}$ | 1.710 | 0.721 | 1.257 | 0.919 | 2.272 | 1.322 | 1.578 | 1.259 | 1.380 |
| $T_{24}$ | 1.190 | 1.283 | 0.922 | 1.074 | 1.989 | 1.149 | 1.215 | 0.769 | 1.199 |

Table 9. Mixing indexes of K.S.U. conventional screw. Test #3

| | Sample # | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M.I. at | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | MEAN |
| $T_o$ | 1.036 | 1.176 | 1.291 | 0.878 | 0.715 | 1.122 | 1.036 | 1.036 | 1.036 |
| $T_{12}$ | 1.027 | 1.190 | 1.742 | 0.749 | 1.226 | 0.934 | 1.150 | 1.187 | 1.151 |
| $T_{24}$ | 1.289 | 0.771 | 1.164 | 1.435 | 1.176 | 0.979 | 1.265 | 0.699 | 1.097 |

Table 10. Total average of mixing indexes in three tempering tests by K.S.U. conventional screw.

| M.I. MEAN at | Test 1 | Test 2 | Test 3 | Total MEAN |
|---|---|---|---|---|
| $T_o$ | 0.949 | 1.435 | 1.036 | 1.140 |
| $T_{12}$ | 1.106 | 1.380 | 1.151 | 1.212 |
| $T_{24}$ | 1.041 | 1.199 | 1.097 | 1.112 |

Table 11. Standard deviation of moisture content in dry wheat.

| System | Test 1 | Test 2 | Test 3 | Average |
|---|---|---|---|---|
| Intensive mixer | 1.316 | 1.795 | 2.040 | 1.717 |
| K.S.U. conventional screw | 2.130 | 2.010 | 2.320 | 2.153 |

Table 12. Mixing indexes data analysis. General linear model procedure.

Dependent Variable: M.I.

| Source | DF | Sum of Squares | MEAN Square | F Value | PR > F | R-Square | C.V. |
|---|---|---|---|---|---|---|---|
| Model | 5 | 0.61111064 | 0.12222213 | 1.21 | 0.3078 | 0.044127 | 28.4154 |
| Error | 131 | 13.23769369 | 0.10105110 | Std. Dev | | | M.I. MEAN |
| Corrected Total | 136 | 13.84880432 | | 0.31788535 | | | 1.11870803 |

| Source | DF | Type IV SS | F Value | PR > F |
|---|---|---|---|---|
| System | 1 | 0.29674368 | 2.94 | 0.0890+ |
| Time | 2 | 0.21221458 | 1.05 | 0.3529 |
| Time X System | 2 | 0.09902117 | 0.49 | 0.6138 |

Least Square Means

| Time | M.I. LS Mean | System | M.I. LS Mean |
|---|---|---|---|
| $T_o$ | 1.15317083 | SA | 1.07479167+ |
| $T_{12}$ | 1.14489394 | SB | 1.16807760 |
| $T_{24}$ | 1.06623913 | | |

+ Significant at 10% level

trend was noted between the three KSU conventional screw tempering tests. However, the overall average tabulated in 10 under total mean, shows that at 24 hours after mixing, single kernel moisture variations were higher than that of dry wheat.

A statistical analysis (Table 12) using a linear procedure showed that no time or system x time effects were noted. The only significant difference observed was between systems. At 10% level of significance, the intensive mixer resulted in a lower MI least square mean which means lower moisture content disparity between kernels.

Summary

Both systems increased moisture content variation between wheat kernels immediately after temper. As temper time continued, the moisture variation decreased. At 24 hours after mixing, the tempered wheat had nearly the same moisture content variations as the dry wheat when intensive mixer tempered. When using the KSU conventional screw, the variation in moisture content between kernels at 24 hours was higher than the dry wheat by as much as 11.2%.

Experimental milling

The second objective of our investigation was to evaluate the milling behaviors of the same variety of hard red winter wheat tempered through the intensive mixer and the KSU conventional screw.

The Miag Multomat experimental mill was used to run ten millings (5 millings per temper time) on wheat held for 12 and 24 hours after being tempered by the intensive mixer, and 11 millings (5 millings at 12 hours and 6 millings at 24 hours) on wheat held for 12 and 24 hours after being tempered through the KSU conventional screw.

These millings were performed on different days and all streams were collected separately and checked for moisture, ash, protein, and green filter agtron color and joined together to form a straight grade which was checked for moisture, ash, protein, and color.

All milling results tabulated per order of milling, tempering system, and temper time are shown in Tables 13 through 22.

Throughout the following discussion, SA,SB stand for system A and B previously referred to as intensive mixer and conventional screw and $T_0$, $T_{12}$, $T_{24}$ stand for time: immediately after tempering, 12 and 24 hours later.

From the analysis of flour streams of different samples milled on the Miag Multomat, total averages were computed and cumulative ash, protein, and color were drawn in order of increasing ash as shown in Figures 4 through 15. The mean ash content of different mills was arranged in increasing order; the mean percent of total product for each flour stream was reported and summed in the order of increasing ash. Each stream percent was then multipled by its respective ash content and then summed in the order of increasing ash. The cumulative percent of total product times percent ash as divided by the cumulative percent of ash as it is shown in Tables 17 and 18.

The total cumulative percent ash of straight grade flour and the patent flour at 0.35% ash (Table 16 was obtained from the cumulative ash calculations. These values along with the total percent extraction of straight grade flour were used to calculate the materials value for each tempering system.

Table 13. Straight grade flour percent extraction per milling run at 12 and 24 hours of tempered wheat with intensive mixer (SA) and K.S.U. conventional screw (SB). The milling runs were performed per set of three (at 12 and 24 hr temper) on different days.

| Milling Run# | SA,$T_{12}$ | SA,$T_{24}$ | SB,$T_{12}$ | SB,$T_{24}$ |
|---|---|---|---|---|
| 1 | 67.82 | 70.44 | 70.56 | 70.84 |
| 2 | 69.57 | 69.42 | 71.38 | 71.03 |
| 3 | -- * | -- * | 71.00 | 70.76 |
| Average+ | 68.70 | 69.93 | 70.98 | 70.88 |
| 4 | 72.24 | 73.37 | 71.88 | 71.57 |
| 5 | 71.71 | 72.57 | 71.47 | 71.82 |
| 6 | 71.77 | 73.06 | -- * | 71.90 |
| Average+ | 71.91 | 73.00 | 71.68 | 71.76 |
| MEAN | 70.31 | 71.47 | 71.33 | 71.32 |

* Data not available

\+ Average of milling runs on the same day for each tempering system.

Table 14. Straight grade flour moisture content from different milling runs at 12 and 24 hours of tempered wheat with intensive mixer (SA) and K.S.U. conventional screw (SB).

| Milling Run # | $SA,T_{12}$ | $SA,T_{24}$ | $SB,T_{12}$ | $SB,T_{24}$ |
|---|---|---|---|---|
| 1 | 15.0 | 13.3 | 14.7 | 15.0 |
| 2 | 14.1 | 13.8 | 14.4 | 14.1 |
| 3 | -- * | -- * | 14.3 | 13.9 |
| Average+ | 14.6 | 13.6 | 14.5 | 14.3 |
| 4 | 14.7 | 14.7 | 14.8 | 14.3 |
| 5 | 14.4 | 14.5 | 14.2 | 14.5 |
| 6 | 14.2 | 14.3 | -- * | 14.4 |
| Average+ | 14.4 | 14.5 | 14.5 | 14.4 |
| MEAN | 14.5 | 14.1 | 14.5 | 14.4 |

+ Average of milling data run on the same day for each tempering system.

* Data not available.

In calculating the materials value (Table 23), each product percentage was multipled by its respective market price per hundred pounds. On that date, patent flour was selling for $10.00/cwt., clear for $8.27/cwt., and feed for $5.00/cwt.

The products were then summed to obtain the materials value in dollar per hundred weight milled.

Cumulative color* and protein curves were also plotted for both tempering systems at 12 and 24 hours temper time. They were calculated on the basis of increasing ash content. All calculations were the same as that for cumulative percent ash at a 14% moisture basis.

Flour analysis

Tests of significance for the statistical analyses were performed on straight grade flour extraction (Table 13). It was found that system and time had no significant effect on the percentage of flour yield as well as its moisture content (Tables 13 and 14).

Data from different millings showed a singificant day and milling effect, caused by some uncontrolled variables in the milling process. The two first milling runs performed on wheat after being tempered by the intensive mixer showed lower extraction than those done later, because that day, the room temperature was fluctuating and the break rolls were set a little bit loose.

Summary

The percent ash in straight grade flour was affected by the type of tempering system used at the 10% level of significance. Data in

* Tables 21 and 22, the color of streams in straight grade flour was assumed to be additive.

Table 15. Straight grade flour percent ash, protein, and color. Averages per day of milling, temper time, and tempering system.

| Tempering System | Milling Day # | Percent ash $T_{12}$ | Percent ash $T_{24}$ | Percent Protein $T_{12}$ | Percent Protein $T_{24}$ | Agtron color $T_{12}$ | Agtron color $T_{24}$ |
|---|---|---|---|---|---|---|---|
| Intensive Mixer | 1 | .406 | .421 | 12.50 | 12.52 | 116 | 114 |
| | 2 | .441 | .424 | 12.69 | 12.83 | 114 | 116 |
| | MEAN | .424 | .423 | 12.60 | 12.68 | 115 | 115 |
| K.S.U. Conventional Screw | 3 | .445 | .453 | 12.90 | 12.58 | 110 | 111 |
| | 4 | .442 | .444 | 12.93 | 12.87 | 113 | 110 |
| | MEAN | .444 | .449 | 12.92 | 12.73 | 111.5 | 110.5 |

Table 16. Patent flour percent extraction, percent protein, and color at 0.35% ash content. Averages per day of milling, temper time, and tempering system.

| Tempering System | Milling Day # | Patent % extraction $T_{12}$ | Patent % extraction $T_{24}$ | Percent Protein $T_{12}$ | Percent Protein $T_{24}$ | Agtron color $T_{12}$ | Agtron color $T_{24}$ |
|---|---|---|---|---|---|---|---|
| Intensive mixer | 1 | 55.80 | 57.55 | 12.254 | 12.180 | 122.6 | 121.0 |
| | 2 | 51.21 | 59.72 | 12.208 | 12.641 | 123.2 | 122.0 |
| | Average | 55.01 | 58.64 | 12.231 | 12.411 | 122.9 | 121.5 |
| K.S.U. Conventional Screw | 3 | 49.54 | 46.07 | 12.30 | 11.63 | 119.1 | 120.0 |
| | 4 | 45.78 | 48.53 | 12.53 | 11.93 | 125.0 | 118.2 |
| | Average | 47.66 | 47.30 | 12.42 | 11.78 | 122.1 | 119.1 |

Table 17. Cumulative ash calculations
Intensive mixer
12 & 24 hours temper time
(Total average)

| | Q | S of Q | A | Q x A | S of Q x A | S of Q x A / S of Q | |
|---|---|---|---|---|---|---|---|
| Flour Stream | % of total product | cumulative % of total products | % Ash 14% M.B. | % of total product X % Ash | Cumulative Q x A | Cumulative % of Ash | Temper time in hour |
| 1MR | 7.777 | 7.777 | .305 | 2.372 | 2.372 | .305 | 12 |
| 2M | 21.178 | 28.955 | .330 | 6.989 | 9.361 | .323 | 12 |
| 1M | 11.335 | 40.290 | .340 | 3.854 | 13.215 | .328 | 12 |
| 2BK | 5.878 | 46.168 | .405 | 2.381 | 15.596 | .338 | 12 |
| 1BK | 7.320 | 53.488 | .405 | 2.965 | 18.561 | .347 | 12 |
| Gr | 3.517 | 57.005 | .470 | 1.653 | 20.214 | .355 | 12 |
| 3M | 7.208 | 64.213 | .500 | 3.604 | 23.818 | .371 | 12 |
| 3BK | 2.831 | 67.044 | .545 | 1.543 | 25.361 | .378 | 12 |
| 4M | 2.619 | 69.663 | 1.150 | 3.012 | 28.373 | .407 | 12 |
| 5M | 0.658 | 70.321 | 2.150 | 1.415 | 29.788 | .424 | 12 |
| 1MR | 7.866 | 7.866 | .305 | 2.399 | 2.399 | .305 | 24 |
| 1M | 11.457 | 19.323 | .325 | 3.724 | 6.123 | .317 | 24 |
| 2M | 22.346 | 41.669 | .340 | 7.598 | 13.721 | .329 | 24 |
| 1BK | 7.255 | 48.924 | .385 | 2.793 | 16.514 | .338 | 24 |
| 2BK | 5.940 | 54.864 | .390 | 2.317 | 18.831 | .343 | 24 |
| Gr | 3.587 | 58.451 | .450 | 1.614 | 20.445 | .350 | 24 |
| 3M | 6.976 | 65.427 | .530 | 3.697 | 24.142 | .369 | 24 |
| 3BK | 3.155 | 68.582 | .595 | 1.877 | 26.019 | .379 | 24 |
| 4M | 2.262 | 70.844 | 1.200 | 2.714 | 28.733 | .406 | 24 |
| 5M | 0.638 | 71.482 | 2.300 | 1.467 | 30.200 | .422 | 24 |

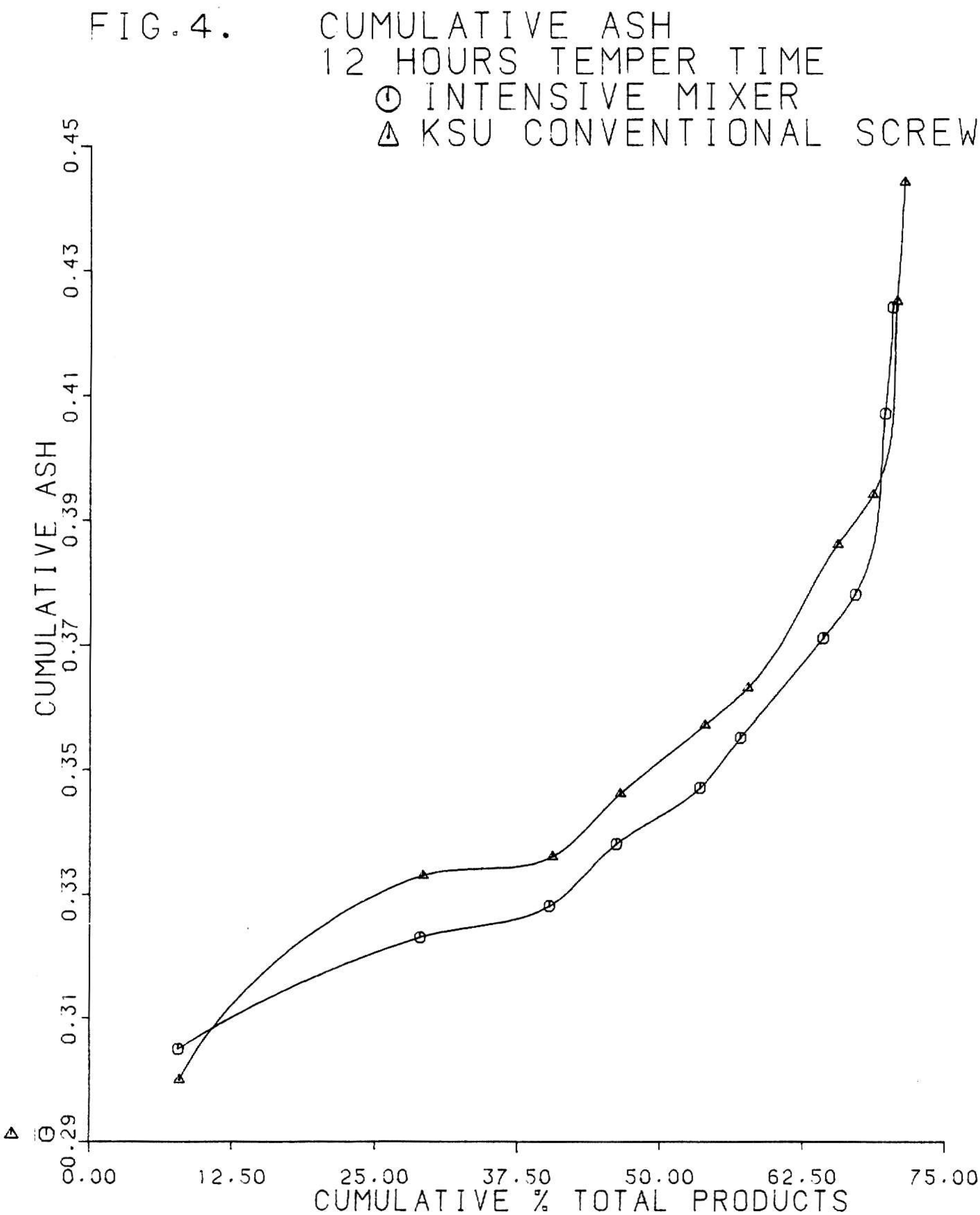
A = Ash (14% M.B.)
Q = Quantity (% of total product)
S - Summation of flours

Table 18. Cumulative Ash Calculations
K.S.U. Conventional Screw
12 & 24 Hours Temper Time
(Total Average)

| | Q | S of Q | A | Q x A | S of Q x A | $\frac{\text{S of Q x A}}{\text{S of Q}}$ | |
|---|---|---|---|---|---|---|---|
| Flour Stream | % of total product | cumulative % of total products | % Ash 14% M.B. | % of total product X % Ash | Cumulative Q X A | Cumulative % of Ash | Temper Time in hour |
| 1MR | 7.89 | 7.89 | .300 | 2.367 | 2.367 | .300 | 12 |
| 2M | 21.295 | 29.185 | .345 | 7.347 | 9.714 | .333 | 12 |
| 1M | 11.375 | 40.560 | .345 | 3.924 | 13.638 | .336 | 12 |
| 2BK | 5.950 | 46.510 | .410 | 2.440 | 16.078 | .346 | 12 |
| 1BK | 7.375 | 53.885 | .430 | 3.171 | 19.249 | .357 | 12 |
| Gr | 3.775 | 57.660 | .445 | 1.680 | 20.929 | .363 | 12 |
| 3M | 7.800 | 65.460 | .555 | 4.329 | 25.258 | .386 | 12 |
| 3BK | 3.135 | 68.595 | .565 | 1.771 | 27.029 | .394 | 12 |
| 4M | 2.095 | 70.690 | 1.450 | 3.038 | 30.067 | .425 | 12 |
| 5M | 0.645 | 71.335 | 2.450 | 1.580 | 31.647 | .444 | 12 |
| 1MR | 7.745 | 7.745 | .310 | 2.401 | 2.401 | .310 | 24 |
| 1M | 10.850 | 18.595 | .345 | 3.743 | 6.144 | .330 | 24 |
| 2M | 21.985 | 40.580 | .350 | 7.695 | 13.839 | .341 | 24 |
| 1BK | 7.125 | 47.705 | .405 | 2.886 | 16.725 | .351 | 24 |
| 2BK | 6.240 | 53.945 | .425 | 2.652 | 19.377 | .359 | 24 |
| Gr | 3.930 | 57.875 | .470 | 1.847 | 21.224 | .367 | 24 |
| 3M | 7.405 | 65.280 | .560 | 4.147 | 25.371 | .389 | 24 |
| 3BK | 3.080 | 68.360 | .615 | 1.894 | 27.265 | .399 | 24 |
| 4M | 2.275 | 70.635 | 1.400 | 3.185 | 30.450 | .431 | 24 |
| 5M | 0.675 | 71.310 | 2.350 | 1.586 | 32.036 | .449 | 24 |

A = Ash (14% moisture basis)
Q = Quantity (% of total product)
S = Summation of flours

FIG.4.


CUMULATIVE ASH
12 HOURS TEMPER TIME
INTENSIVE MIXER
KSU CONVENTIONAL SCREW
CUMULATIVE ASH
0.29
0.31
0.33
0.35
0.37
0.39
0.41
0.43
0.45
0.00
12.50
25.00
37.50
50.00
62.50
75.00
CUMULATIVE % TOTAL PRODUCTS

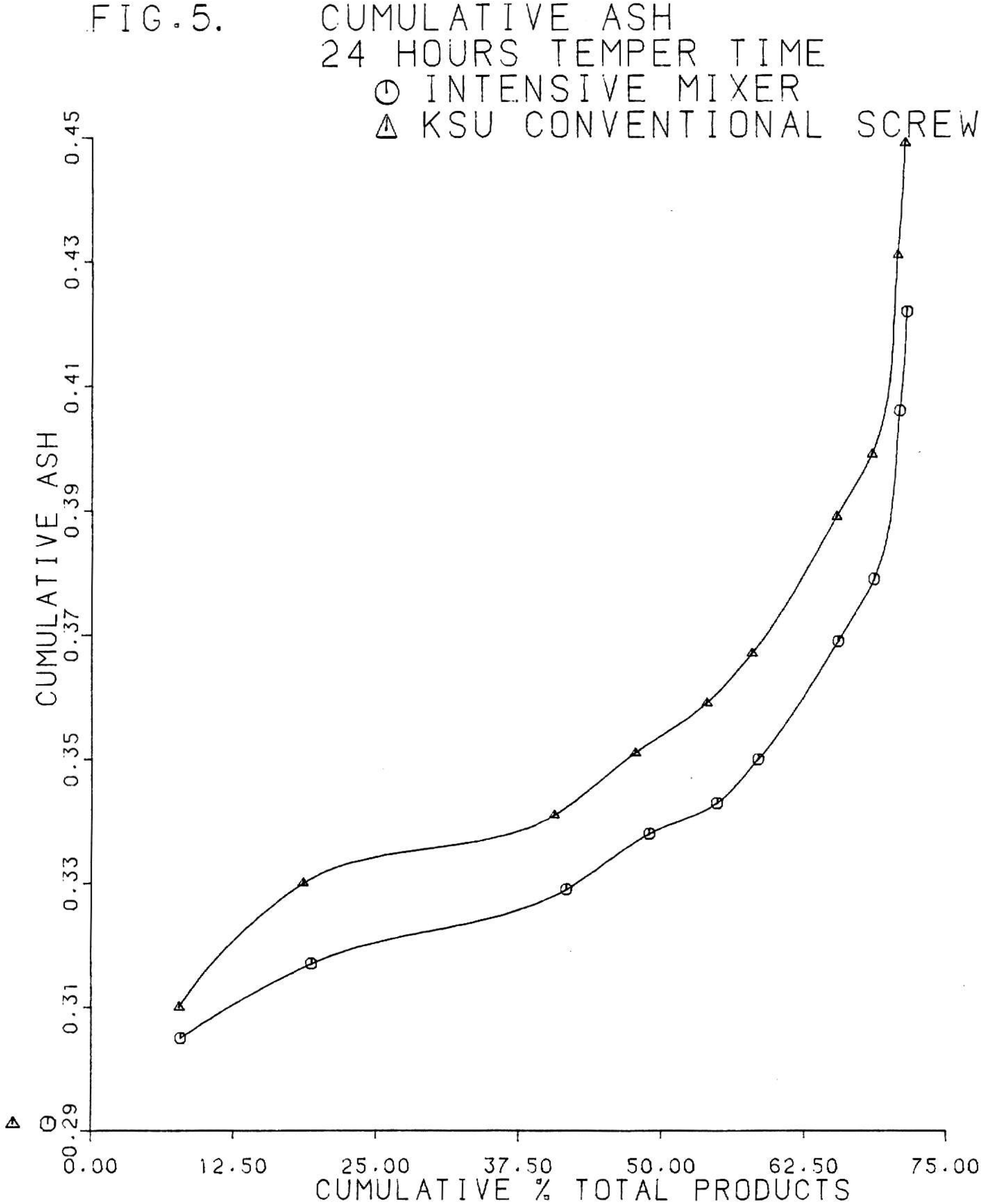
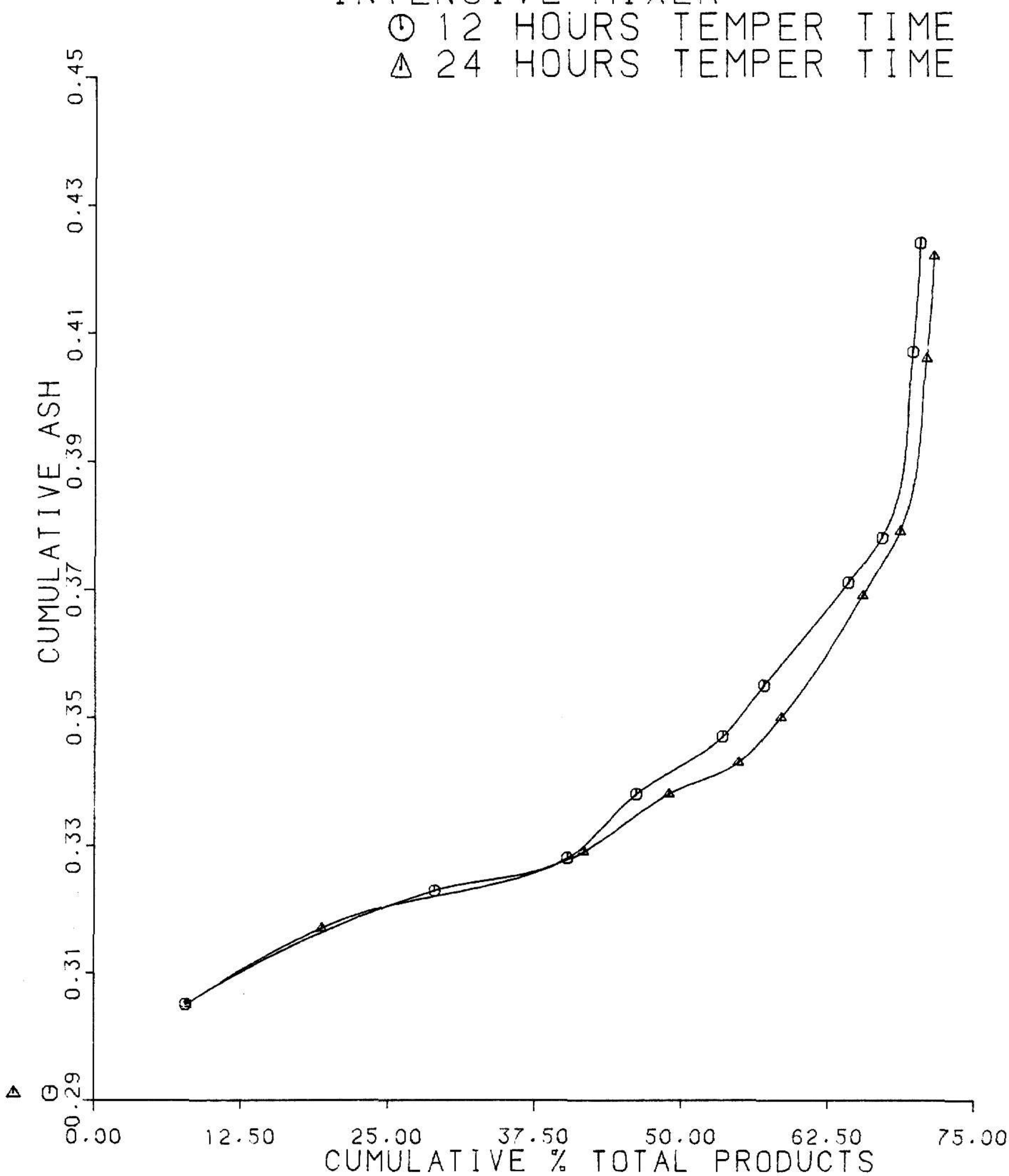


FIG. 5. CUMULATIVE ASH
24 HOURS TEMPER TIME
INTENSIVE MIXER
KSU CONVENTIONAL SCREW
CUMULATIVE ASH
0.29
0.31
0.33
0.35
0.37
0.39
0.41
0.43
0.45
0.00
12.50
25.00
37.50
50.00
62.50
75.00
CUMULATIVE % TOTAL PRODUCTS

FIG.6. CUMULATIVE ASH INTENSIVE MIXER



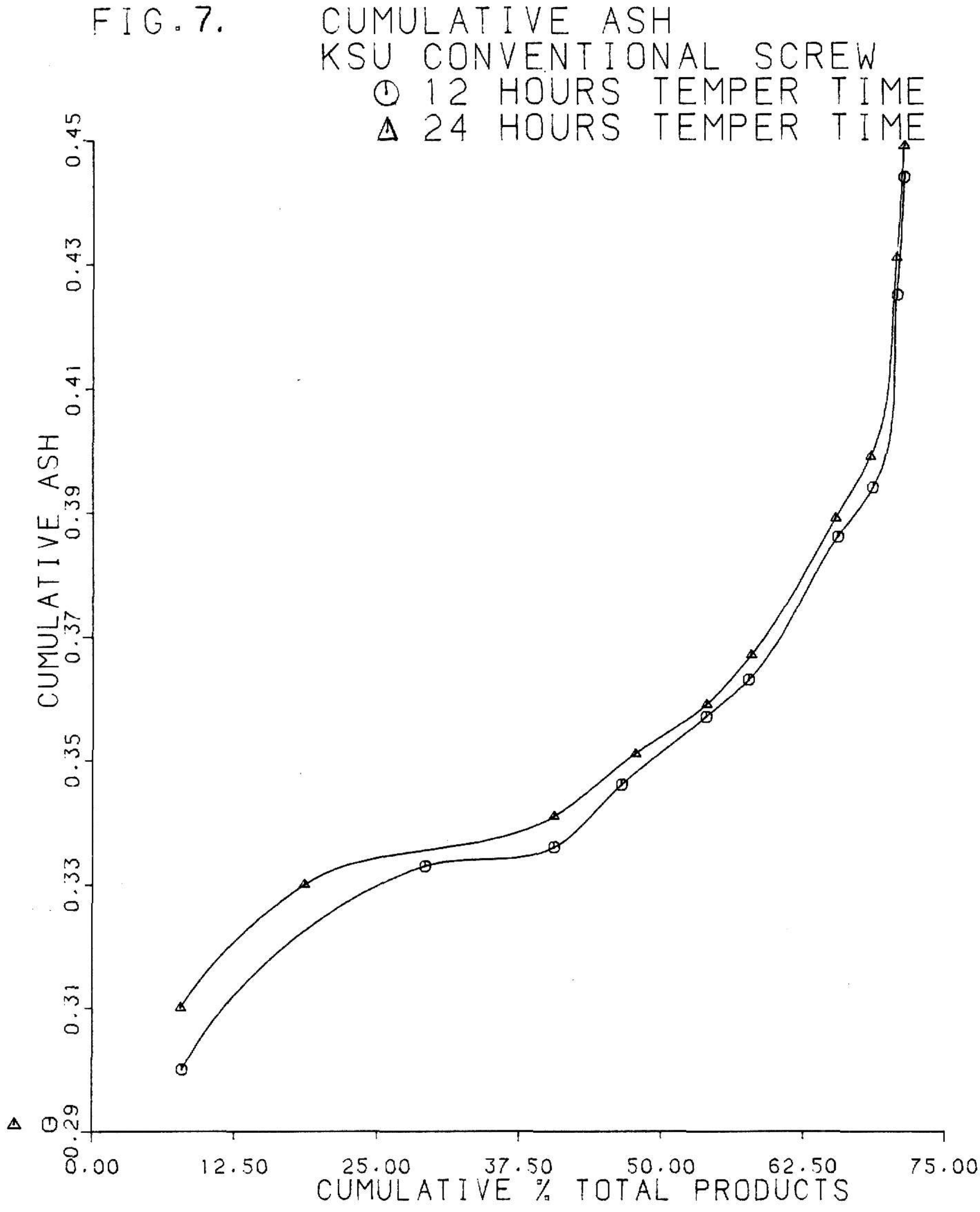


FIG. 7. CUMULATIVE ASH
KSU CONVENTIONAL SCREW
12 HOURS TEMPER TIME
24 HOURS TEMPER TIME
CUMULATIVE ASH
0.29
0.31
0.33
0.35
0.37
0.39
0.41
0.43
0.45
0.00
12.50
25.00
37.50
50.00
62.50
75.00
CUMULATIVE % TOTAL PRODUCTS

Tables 15, 17, 18 and Figures 4, 5, 6, 7 show that although there was but little variability in ash content between temper time within each tempering system, there was a significant difference in the cumulative ash curves between both systems at 12 and 24 hours temper time. Figures 4 and 5 show clearly that the intensive mixer had lower cumulative ash percent at 12 and 24 hours.

Twelve and 24 hours temper appear to give nearly the same cumulative ash percent within each tempering system (Figures 6 and 7).

The method of tempering had a significant effect at 1% level on flour color. Tables 21, 22 and Figures 12 and 13 show that the cumulative green filter agtron color was lower or darker in flour obtained from samples tempered in the KSU conventional screw at 12 as well as 24 hours. Little color difference was noted between 12 and 24 hours within each tempering system (Figures 14 and 15).

While ash content and agtron color of flour vary from one tempering system to another, the protein recovery (protein % of flour) did not demonstrate a consistent trend as shown in Tables 19, 20 and Figures 8, 9, 10 and 11.

Figure 8 shows that at 12 hours, the conventional screw gave higher protein recovery. The amount of protein recovered at 12 hours temper when using the conventional screw was also higher than that at 24 hours (Figure 11).

Patent flour

Patent flour characteristics at 0.35% ash were drawn from cumulative ash, protein and color calculation tables. Patent flour percent extraction,

Table 19. Cumulative Protein Calculations
Intensive mixer
12 & 24 hours temper time
(Total average)

| | Q | S of Q | P | Q x P | S of Q x P | S of Q x P / S of Q | |
|---|---|---|---|---|---|---|---|
| Flour Steam | % of total products | cumula-tive % total products | % pro-tein 14% M.B. | % of total product X % protein | cumula-tive Q x P | Cumulative % of protein | Temper time in hour |
| 1MR | 7.777 | 7.777 | 11.60 | 90.213 | 90.213 | 11.60 | 12 |
| 2M | 21.178 | 28.955 | 11.40 | 241.429 | 331.642 | 11.45 | 12 |
| 1M | 11.335 | 40.290 | 11.75 | 133.186 | 464.828 | 11.54 | 12 |
| 2BK | 5.878 | 46.168 | 15.70 | 92.285 | 557.113 | 12.07 | 12 |
| 1BK | 7.320 | 53.488 | 13.40 | 98.088 | 655.201 | 12.25 | 12 |
| Gr | 3.517 | 57.005 | 13.55 | 47.655 | 702.856 | 12.33 | 12 |
| 3M | 7.208 | 64.213 | 12.50 | 90.100 | 792.956 | 12.35 | 12 |
| 3BK | 2.831 | 67.044 | 16.85 | 47.702 | 840.658 | 12.54 | 12 |
| 4M | 2.619 | 69.663 | 13.40 | 35.095 | 875.753 | 12.57 | 12 |
| 5M | 0.658 | 70.321 | 15.45 | 10.166 | 885.919 | 12.60 | 12 |
| 1MR | 7.866 | 7.866 | 11.75 | 92.426 | 92.426 | 11.75 | 24 |
| 1M | 11.457 | 19.323 | 11.90 | 136.338 | 228.764 | 11.84 | 24 |
| 2M | 22.346 | 41.669 | 11.55 | 258.096 | 486.860 | 11.68 | 24 |
| 1BK | 7.255 | 48.924 | 13.20 | 95.766 | 582.626 | 11.91 | 24 |
| 2BK | 5.940 | 54.864 | 15.95 | 94.743 | 677.369 | 12.35 | 24 |
| Gr | 3.587 | 58.451 | 13.60 | 48.783 | 726.152 | 12.42 | 24 |
| 3M | 6.976 | 65.427 | 12.75 | 88.944 | 815.096 | 12.46 | 24 |
| 3BK | 3.155 | 68.582 | 15.90 | 50.165 | 865.261 | 12.62 | 24 |
| 4M | 2.262 | 70.844 | 13.80 | 31.216 | 896.477 | 12.65 | 24 |
| 5M | 0.638 | 71.482 | 15.80 | 10.080 | 906.557 | 12.68 | 24 |

P = Protein (14% moisture Basis)
Q = Quantity (% of total product)
S = Summation of flours

Table 20. Cumulative Protein Calculations
K.S.U. Conventional Screw
12 & 24 Hours Temper Time
(Total Average)

| Flour Steam | Q<br>% of total products | S of Q<br>cumulative % total products | P<br>% protein 14% M.B. | Q x P<br>% of total product X % protein | S of Q x P<br>cumulative Q & P | S of Q x P / S of Q<br>Cumulative % of Protein | Temper Time in Hour |
|---|---|---|---|---|---|---|---|
| 1Mr | 7.890 | 7.890 | 11.65 | 91.919 | 91.919 | 11.65 | 12 |
| 2M | 21.295 | 29.185 | 11.70 | 249.152 | 341.071 | 11.69 | 12 |
| 1M | 11.375 | 40.560 | 11.80 | 134.225 | 475.296 | 11.72 | 12 |
| 2BK | 5.950 | 46.510 | 15.65 | 93.118 | 568.414 | 12.22 | 12 |
| 1BK | 7.375 | 53.885 | 14.00 | 103.250 | 671.664 | 12.46 | 12 |
| Gr | 3.775 | 57.660 | 13.75 | 51.906 | 723.570 | 12.55 | 12 |
| 3M | 7.800 | 65.460 | 13.50 | 105.300 | 828.870 | 12.66 | 12 |
| 3BK | 3.135 | 68.595 | 17.15 | 53.765 | 882.635 | 12.87 | 12 |
| 4M | 2.095 | 70.690 | 13.55 | 28.387 | 911.022 | 12.89 | 12 |
| 5M | 0.645 | 71.335 | 15.40 | 9.933 | 920.955 | 12.91 | 12 |
| 1MR | 7.745 | 7.745 | 11.55 | 89.455 | 89.455 | 11.55 | 24 |
| 1M | 10.850 | 18.595 | 11.85 | 128.573 | 218.028 | 11.73 | 24 |
| 2M | 21.985 | 40.580 | 11.40 | 250.629 | 468.657 | 11.55 | 24 |
| 1BK | 7.125 | 47.705 | 13.25 | 94.406 | 563.063 | 11.80 | 24 |
| 2BK | 6.240 | 53.945 | 16.05 | 100.152 | 663.215 | 12.29 | 24 |
| Gr | 3.930 | 57.875 | 13.75 | 54.038 | 717.253 | 12.39 | 24 |
| 3M | 7.405 | 65.280 | 12.50 | 92.563 | 809.816 | 12.41 | 24 |
| 3BK | 3.080 | 68.360 | 18.10 | 55.748 | 865.564 | 12.66 | 24 |
| 4M | 2.275 | 70.635 | 13.95 | 31.736 | 897.300 | 12.70 | 24 |
| 5M | 0.675 | 71.310 | 15.10 | 10.193 | 907.493 | 12.73 | 24 |

P = Protein (% Moisture basis)
Q - Quantity (% of total product)
S = Summation of flours

FIG.8. CUMULATIVE PROTEIN
12 HOURS TEMPER TIME

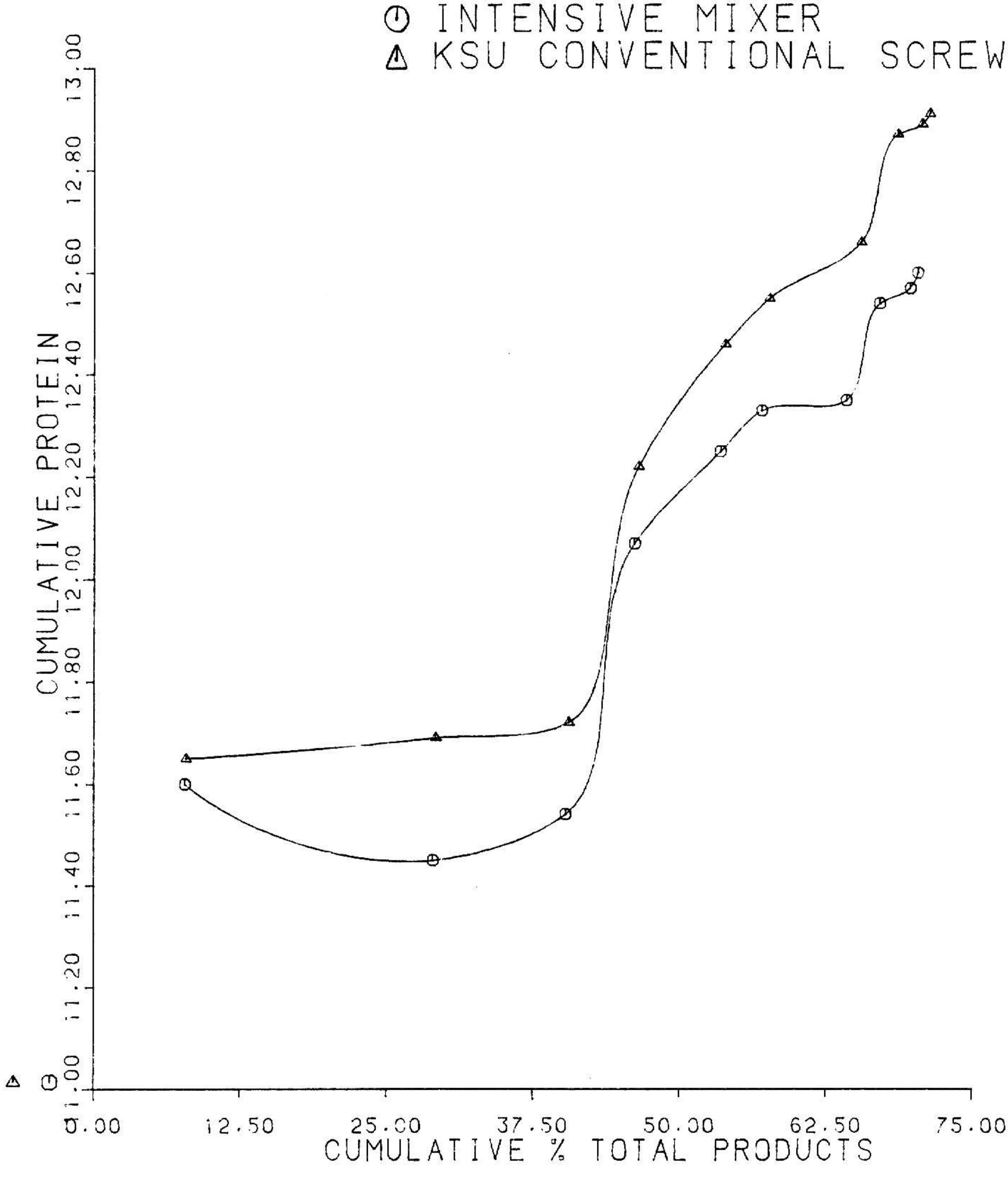


FIG. 9. CUMULATIVE PROTEIN
24 HOURS TEMPER TIME

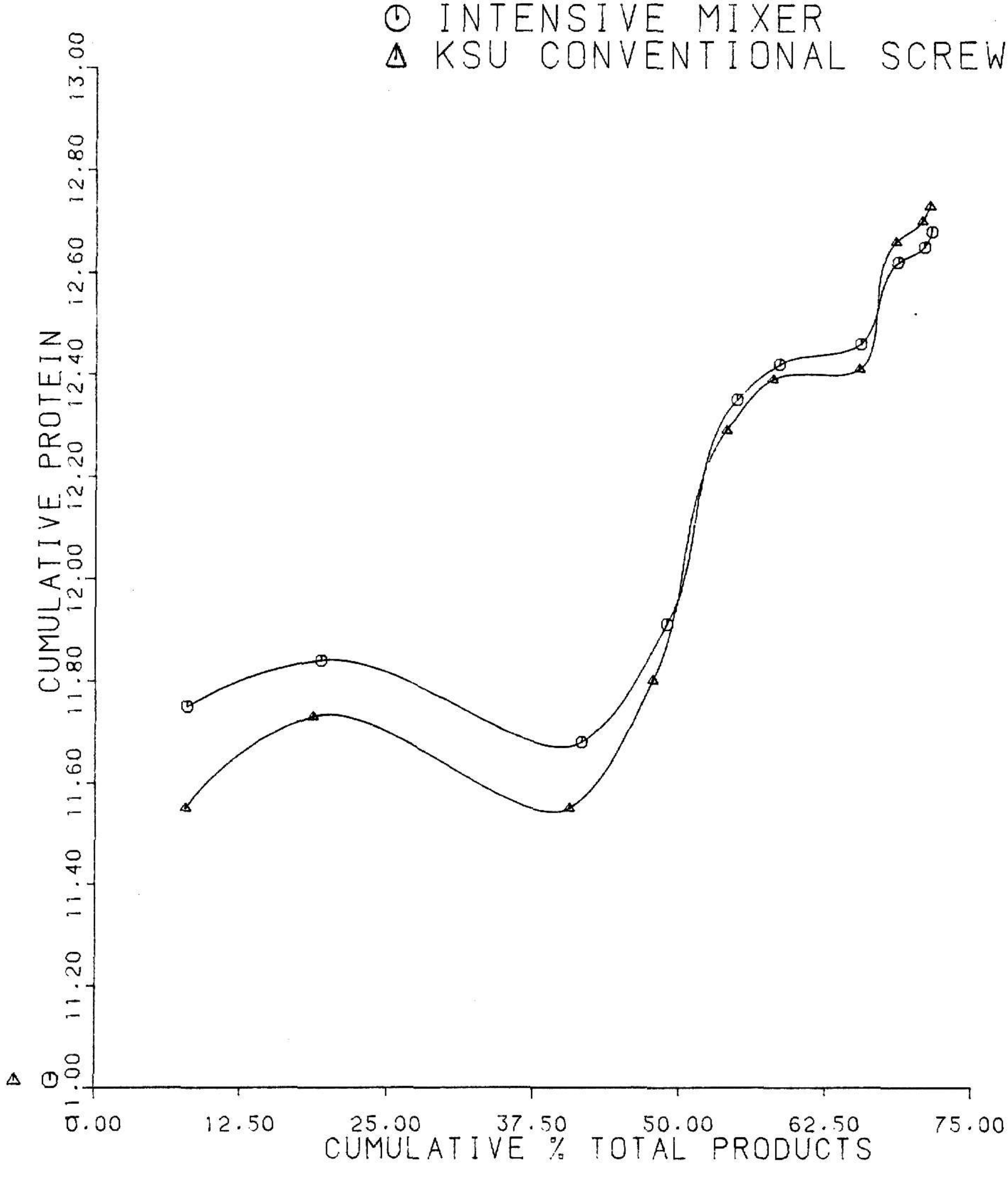
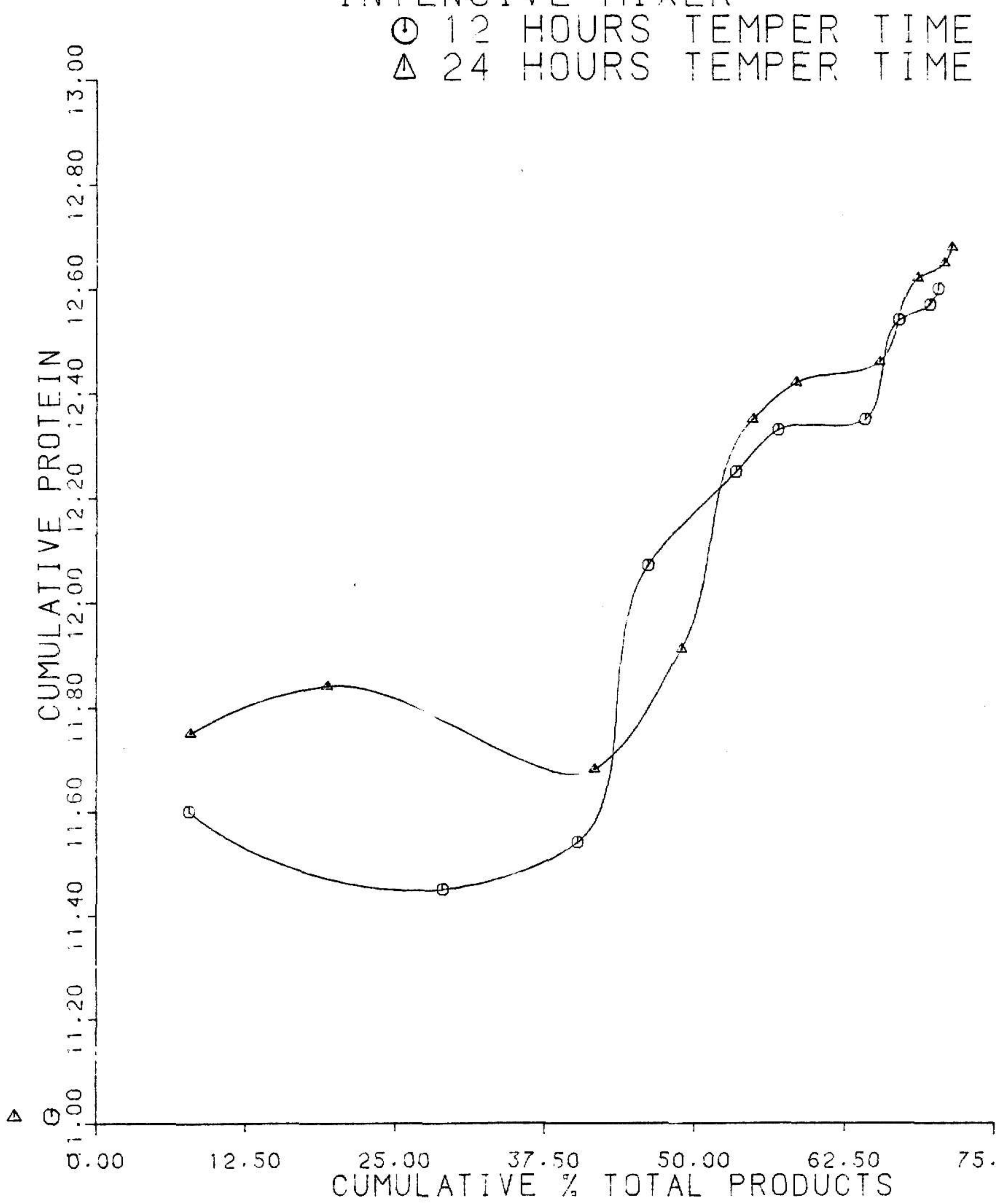


FIG. 10. CUMULATIVE PROTEIN
INTENSIVE MIXER



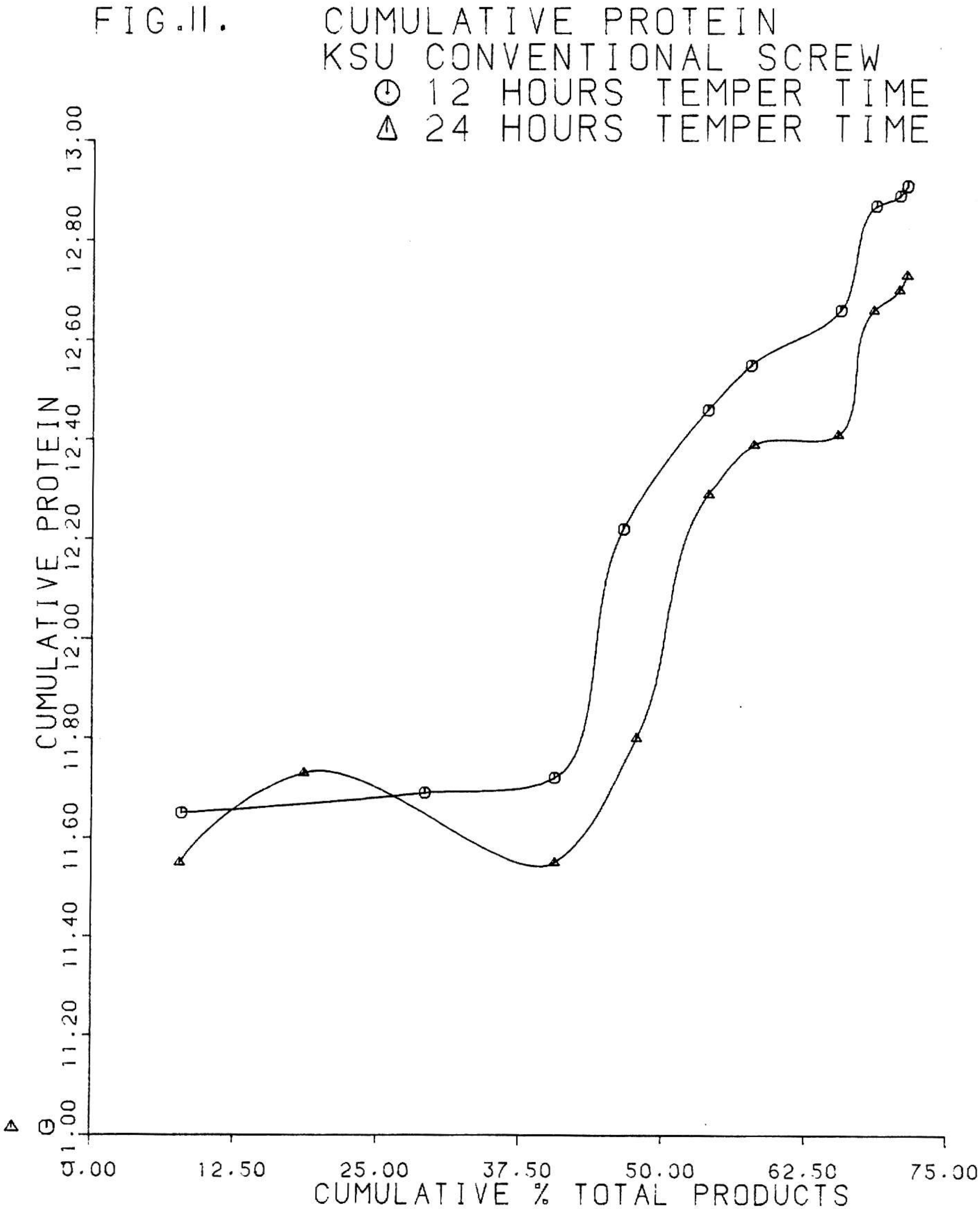


FIG. II. CUMULATIVE PROTEIN
KSU CONVENTIONAL SCREW
⊙ 12 HOURS TEMPER TIME
△ 24 HOURS TEMPER TIME
CUMULATIVE PROTEIN
11.00
11.20
11.40
11.60
11.80
12.00
12.20
12.40
12.60
12.80
13.00
0.00
12.50
25.00
37.50
50.00
62.50
75.00
CUMULATIVE % TOTAL PRODUCTS

Table 21. Cumulative Color Calculations
Intensive Mixer
12 & 24 Hours Temper Time
(Total Average)

| | Q | S of Q | C | Q x C | S of Q x C | S of Q x C / S of Q | Temper Time in Hour |
|---|---|---|---|---|---|---|---|
| Flour Steam | % of total products | cumulative % total products | Color of Streams | % of total product X color | cumulative Q x C | Cumulative Color | |
| 1MR | 7.777 | 7.777 | 131 | 1018.79 | 1018.79 | 131.0 | 12 |
| 2M | 21.178 | 28.955 | 127 | 2689.61 | 3708.40 | 128.1 | 12 |
| 1M | 11.335 | 40.290 | 127 | 1439.55 | 5147.95 | 127.8 | 12 |
| 2BK | 5.878 | 46.168 | 110 | 646.58 | 5794.53 | 125.5 | 12 |
| 1BK | 7.320 | 53.488 | 107 | 783.24 | 6577.77 | 123.0 | 12 |
| 1Gr | 3.517 | 57.005 | 111 | 390.39 | 6968.160 | 122.2 | 12 |
| 3M | 7.208 | 64.213 | 110 | 792.88 | 7761.04 | 120.9 | 12 |
| 3BK | 2.831 | 67.044 | 91 | 257.62 | 8018.66 | 119.6 | 12 |
| 4M | 2.619 | 69.663 | 31 | 81.19 | 8099.85 | 116.3 | 12 |
| 5M | 0.658 | 70.321 | 27 | 17.77 | 8117.62 | 115.4 | 12 |
| 1MR | 7.866 | 7.866 | 130 | 1022.58 | 1022.58 | 130 | 24 |
| 1M | 11.457 | 19.323 | 127 | 1455.04 | 2477.62 | 128.2 | 24 |
| 2M | 22.346 | 41.669 | 125 | 2793.25 | 5270.87 | 126.5 | 24 |
| 1BK | 7.255 | 48.924 | 109 | 790.80 | 6061.67 | 123.9 | 24 |
| 2BK | 5.940 | 54.864 | 111 | 659.34 | 6721.01 | 122.5 | 24 |
| Gr | 3.587 | 58.451 | 112 | 401.74 | 7122.75 | 121.9 | 24 |
| 3M | 6.976 | 65.427 | 105 | 732.48 | 7855.23 | 120.1 | 24 |
| 3BK | 3.155 | 68.582 | 89 | 280.80 | 8136.03 | 118.6 | 24 |
| 4M | 2.262 | 70.844 | 31 | 70.12 | 8206.15 | 115.8 | 24 |
| 5M | 0.638 | 71.482 | 27 | 17.23 | 8223.38 | 115.0 | 24 |

Table 22. CUMULATIVE COLOR CALCULATIONS
K.S.U. CONVENTIONAL SCREW
12 & 24 HOURS TEMPER TIME
(TOTAL AVERAGE)

| | Q | S of Q | C | Q x P | S of Q x P | S of Q x C / S of Q | Temper Time in Hour |
|---|---|---|---|---|---|---|---|
| Flour Steam | % of total products | cumula-tive % total products | Color of Streams | % of total product * color | cumula-tive Q x C | Cumulative Color | |
| 1MR | 7.890 | 7.890 | 128 | 1009.92 | 1009.92 | 128.0 | 12 |
| 2M | 21.295 | 29.185 | 121 | 2576.70 | 3586.62 | 122.9 | 12 |
| 1M | 11.375 | 40.560 | 124 | 1410.50 | 4997.12 | 123.2 | 12 |
| 2BK | 5.950 | 46.510 | 108 | 642.60 | 5639.72 | 121.3 | 12 |
| 1BK | 7.375 | 53.885 | 106 | 781.75 | 6421.47 | 119.2 | 12 |
| GR | 3.775 | 57.660 | 108 | 407.70 | 6829.17 | 118.4 | 12 |
| 3M | 7.800 | 65.460 | 100 | 780.00 | 7609.17 | 116.2 | 12 |
| 3BK | 3.135 | 68.595 | 88 | 275.88 | 7885.05 | 115.0 | 12 |
| 4M | 2.095 | 70.690 | 31 | 64.95 | 7950.00 | 112.5 | 12 |
| 5M | 0.645 | 71.335 | 25 | 16.13 | 7966.13 | 111.7 | |
| 1MR | 7.745 | 7.745 | 129 | 999.11 | 999.11 | 129.0 | 24 |
| 1M | 10.850 | 18.595 | 123 | 1334.55 | 2333.66 | 125.5 | 24 |
| 2M | 21.985 | 40.580 | 118 | 2594.23 | 4927.89 | 121.4 | 24 |
| 1BK | 7.125 | 47.705 | 106 | 755.25 | 5683.14 | 119.1 | 24 |
| 2BK | 6.240 | 53.945 | 109 | 680.16 | 6363.30 | 118.0 | 24 |
| GR | 3.930 | 57.875 | 111 | 436.23 | 6799.53 | 117.5 | 24 |
| 3M | 7.405 | 65.280 | 100 | 740.50 | 7540.03 | 115.5 | 24 |
| 3BK | 3.080 | 68.360 | 87 | 267.96 | 7807.99 | 114.2 | 24 |
| 4M | 2.275 | 70.635 | 31 | 70.53 | 7878.52 | 111.5 | 24 |
| 5M | 0.675 | 71.310 | 25 | 16.875 | 7895.40 | 110.7 | 24 |

FIG. 12. CUMULATIVE AGTRON COLOR
12 HOURS TEMPER TIME

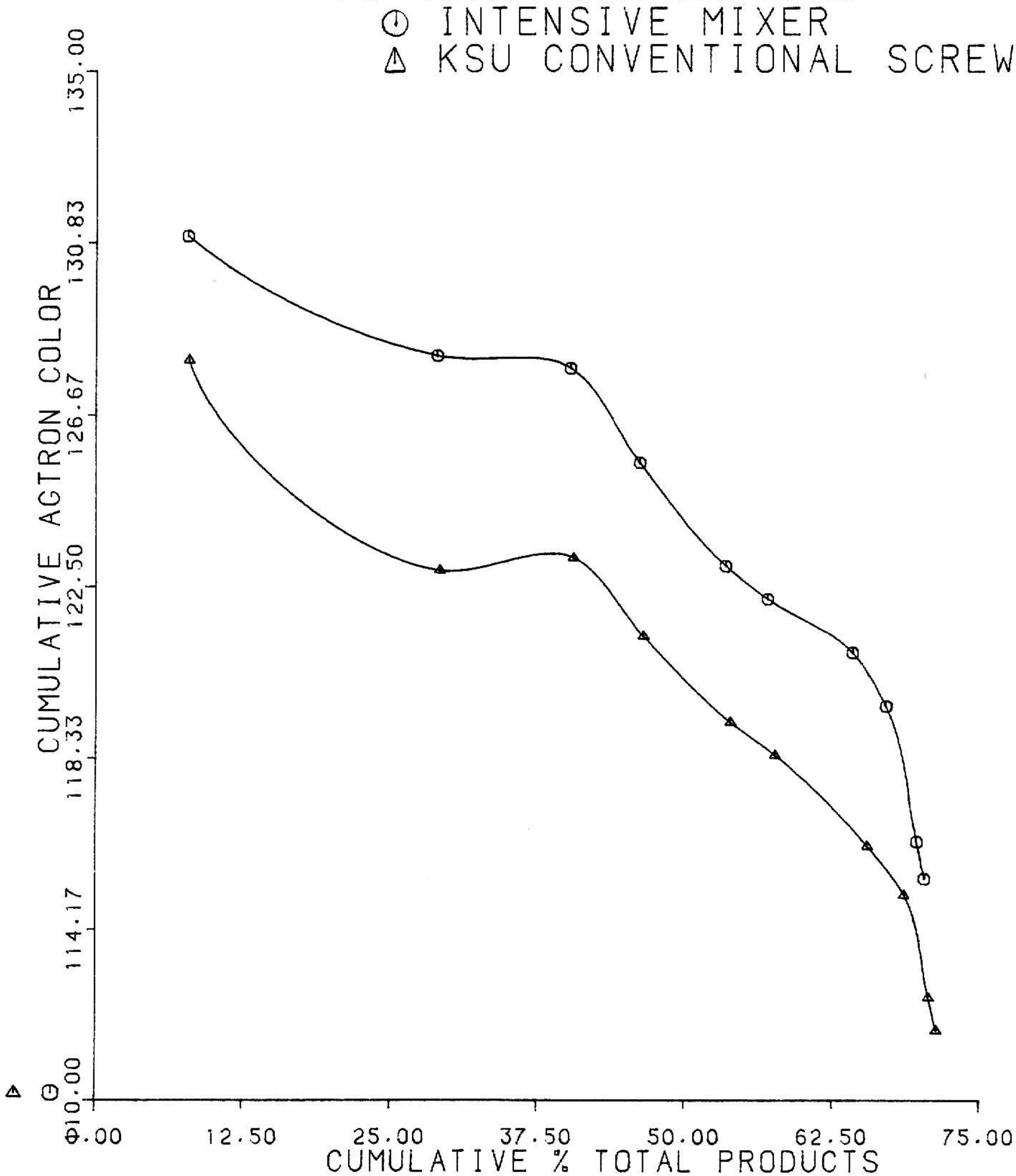


FIG. 13. CUMULATIVE AGTRON COLOR
24 HOURS TEMPER TIME

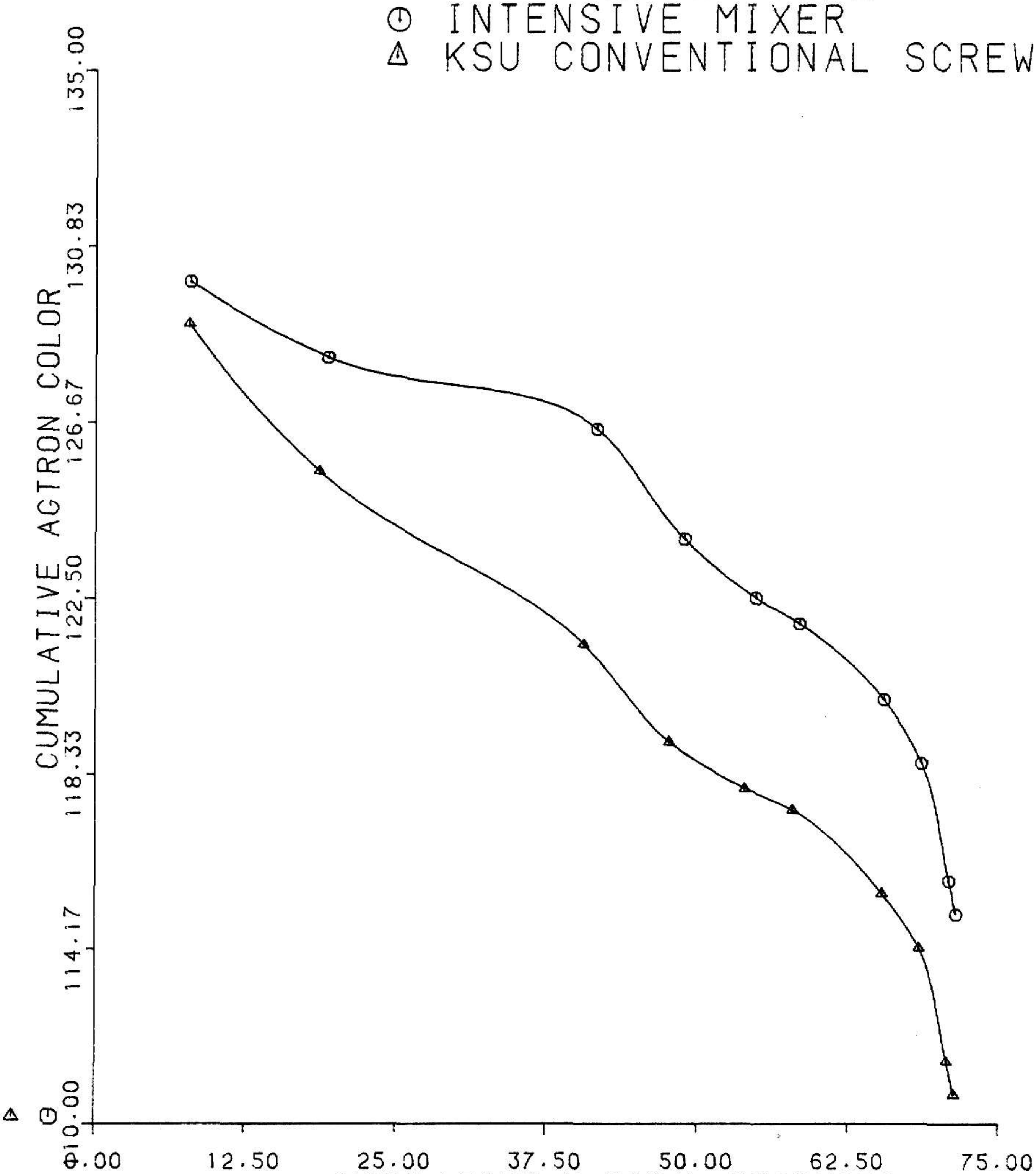
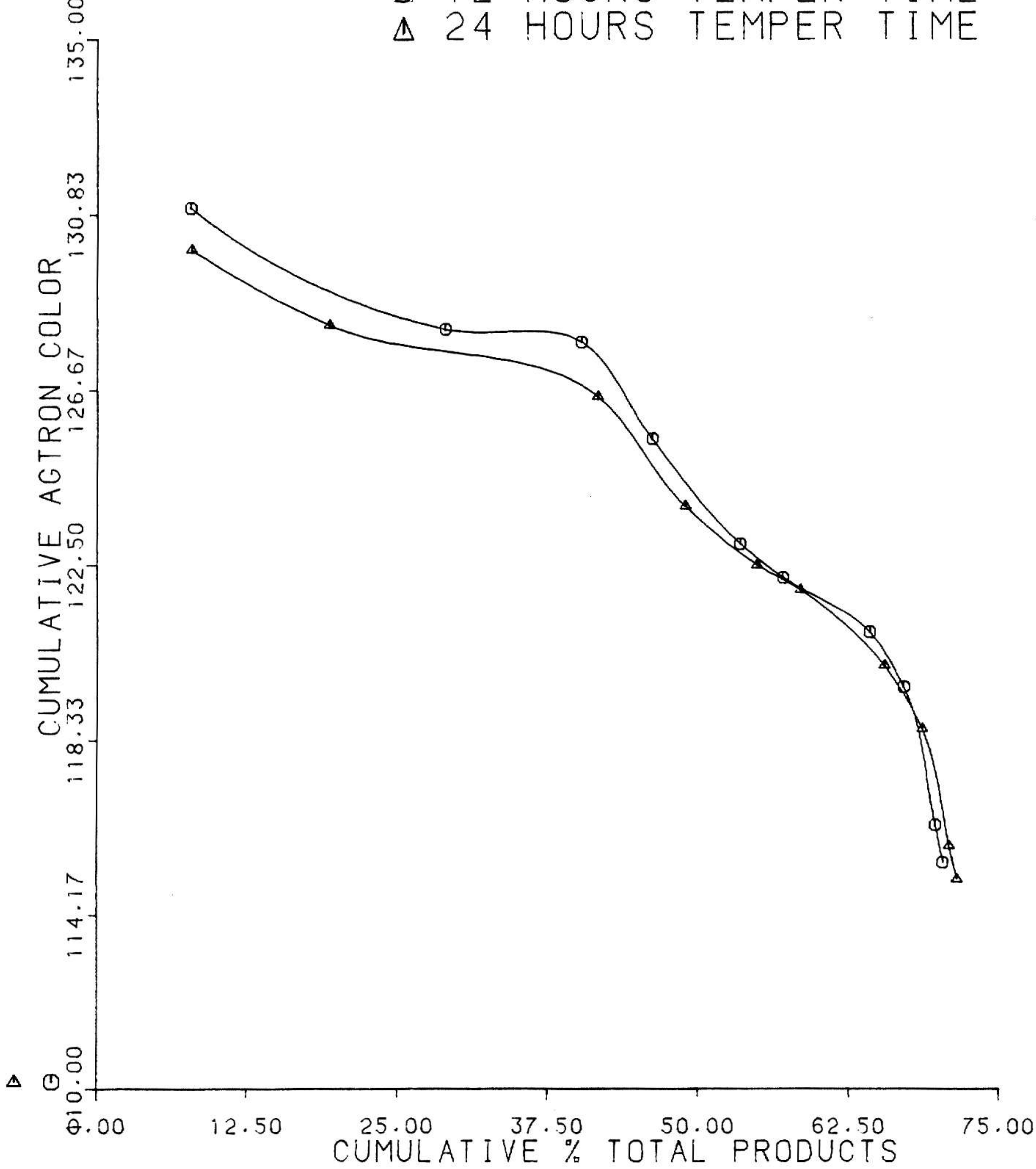


FIG. 14. CUMULATIVE AGTRON COLOR
INTENSIVE MIXER
⊙ 12 HOURS TEMPER TIME
△ 24 HOURS TEMPER TIME



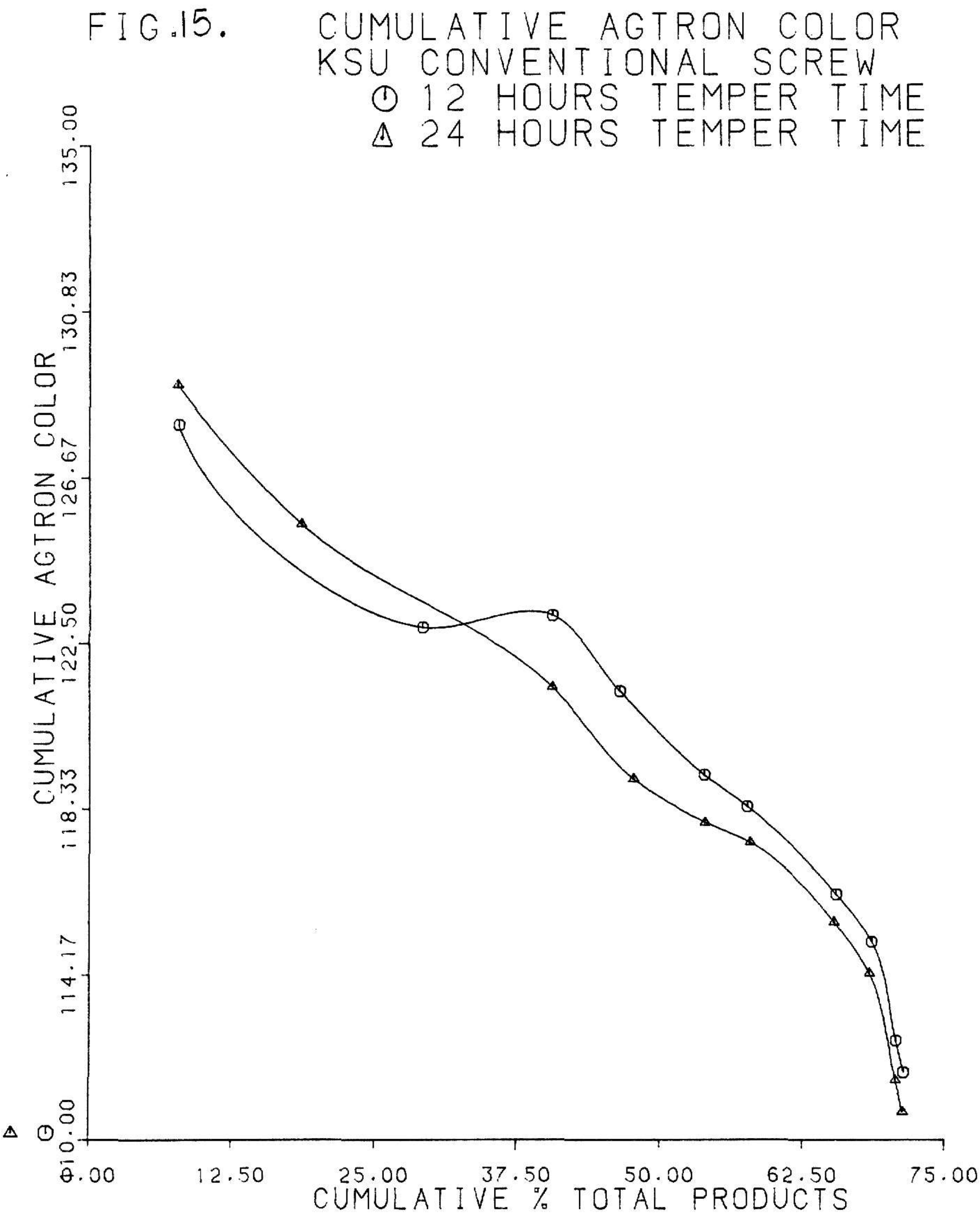


FIG.15. CUMULATIVE AGTRON COLOR
KSU CONVENTIONAL SCREW
12 HOURS TEMPER TIME
24 HOURS TEMPER TIME
CUMULATIVE AGTRON COLOR
135.00
130.83
126.67
122.50
118.33
114.17
110.00
0.00
12.50
25.00
37.50
50.00
62.50
75.00
CUMULATIVE % TOTAL PRODUCTS

Table 23. Grades and values of milling results

| Milling data - Calculation: | Intensive Mixer | | K.S.U. Convent. Screw | |
|---|---|---|---|---|
| Grades and values | 12 Hrs. Temper | 24 Hrs. Temper | 12 Hrs. Temper | 24 Hrs. Temper |
| Patent (%) | 55.01 | 58.64 | 47.66 | 47.30 |
| Ash % (14% M.B.) | .350 | .350 | .350 | .350 |
| Prot % (14% M.B.) | 12.231 | 12.411 | 12.420 | 11.780 |
| Agtron green col. | 122.90 | 121.50 | 122.10 | 119.10 |
| Value/cwt.($) | $10.00 | $10.00 | $10.00 | $10.00 |
| Value ($) | 5.501 | 5.864 | 4.766 | 4.730 |
| Remaining clear (%) | 15.311 | 12.842 | 23.675 | 24.01 |
| Value/cwt ($) | $8.27 | $8.27 | $8.27 | $8.27 |
| Value ($) | 1.266 | 1.062 | 1.958 | 1.986 |
| Millfeed (%) | 29.68 | 28.52 | 28.67 | 28.69 |
| Value/cwt ($) | $5.00 | $5.00 | $5.00 | $5.00 |
| Value ($) | 1.484 | 1.426 | 1.434 | 1.435 |
| Total value/100 lbs ($) | 8.251 | 8.352 | 8.158 | 8.151 |
| Straight grade flour data | | | | |
| Extraction (%) | 70.321 | 71.482 | 71.335 | 71.310 |
| Protein % (14% M.B.) | 12.60 | 12.68 | 12.91 | 12.71 |
| Ash % (14% M.B.) | .424 | .422 | .444 | .449 |
| Agtron green color | 115.4 | 115.0 | 111.7 | 110.7 |

protein content, and color are tabulated in Table 16. This shows that the method of tempering has a singificant effect on patent extraction. Wheat tempered through the intensive mixer gave higher patent extraction at 12 and 24 hours. The differences were 7.35% and 11.34% at 12 and 24 hours respectively.

Time had no effect on patent percent as far as KSU conventional screw is concerned, but it did on intensive mixer tempered wheat. The difference was 3.63% in favor of 24 hours temper.

Temper time made a difference in protein recovery with the conventional screw, but not with the intensive mixer. The type of tempering system made a difference in protein recovery at 24 hours temper. At 24 hours, the conventional screw produced the least amount of protein recovery.

Patent flour produced from samples tempered in the intensive mixer had a brighter color.

Relative dollar value of milled products

Table 23 shows that after assigning relative values for patent flour, clear flour, mill feed and computing the recovered value of the products per 100 lbs of flour, the intensive mixer yielded slightly higher value at 12 as well as 24 hours temper. The differences were \$0.093/cwt and \$0.201/cwt at 12 and 24 hours, respectively.

## Conclusions

In each of the tests described and detailed above, a comparison was made on the performance of an intensive mixer to that of a conventional tempering screw at ambient temperature. Principally, the objective of this work was to investigate whether the intensive mixer had the ability to reduce moisture disparity between wheat kernels, as measured by the mixing index, which would result in flours of higher yield, lower ash, and better color, as has been reported by some milling industries.

The observations, and statistical analysis performed show that both tempering systems increased moisture disparity between wheat kernels immediately after tempering. As temper time continued, the moisture disparity decreased. When tempered with the intensive mixer, at 24 hours, the wet wheat reached nearly the same moisture content variation as the dry wheat; this situation changes when wheat is tempered with the KSU conventional tempering screw, in that a disparity of 11.2% higher than that of dry wheat was observed.

Moisture disparity as affected by the method of tempering, was significant at the 10% level. Milling tests showed that the method of tempering had no significant effect on the percentage of total flour yield.

Cumulative percent ash was affected by the type of tempering system used at the 10% level of significance. The Agtron green filter color of the flour streams was also affected at the 1% level of significance. The intensive mixer gave lower cumulative percent ash and brighter flour color at 12 as well as 24 hours temper than did the conventional screw temper. No clear differences were noted at 12 and 24 hours within each tempering method as far as ash and color are concerned.

The inconsistent trend showed by protein recovery from the different millings was not conclusive.

The recovered total value of products per 100 lbs. of flour was higher in the intensive mixer by $0.093/cwt, and $0.201/cwt at 12 and 24 hours respectively.

It can be concluded that under conditions under which the experiments were performed, the intensive mixer model S-23 was found to perform better with regards to flour ash, Agtron green filter color, and recovered value.

## Suggestions for future work

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

A. A comparison of results obtained in the present investigation to results that are obtained using the two systems in commercial scale mill by treating different wheat mixes and using feed back micro-computer to control wheat and water feed rate fluctuations.

B. Baking tests along with milling tests would be needed for a complete evaluation.

C. Further work should be done in the mechanical action of the intensive mixer paddles upon wheat kernels. It appears that the mechanical action of paddles at high speed disloges the germ, abraids the bran coat and thus might facilitate water penetration into wheat berry.

D. A test of hardness before and after tempering along with the single kernel moisture content determination would be of interest.

E. Moisture disparity between small and big wheat kernels as well as white and dark color kernels could be investigated under careful sampling, rapid weighing, and restricted variations in conditions between the numbered places occupied by the kernels during the course of the determination.

Acknowledgement

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# Effect of method of tempering on single kernel moisture content and milling properties of hard red winter wheat

by

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AN ABSTRACT OF A MASTER'S THESIS

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Wheat conditioning is the preparation of clean wheat for milling using moisture, time, and possibly heat through using various pieces of equipment commonly referred to as tempering system. The success of a given system is based on its ability to facilitate the extraction of the endosperm from the bran and improve the friability of the endosperm so that it can easily be reduced in size to flour, with a minimum of bran contamination.

Among the tempering systems in use nowadays, the intensive mixer has been gaining wide acceptance in the milling industry and was reported superior to other tempering systems by commercial mills.

In this investigation, a comparison was made between the performance of an intensive mixer and a triple tempering conveying screw using cold water, with the wheat at ambient temperature.

The objective was to investigate whether the intensive mixer had the ability to reduce the moisture content disparity between wheat kernels, and thereby give flour of higher yield, lower ash, and whiter color.

A study of milling results, using one variety of Kansas hard red winter wheat, after being tempered by both systems was undertaken. A determination of the water content of individual dry and wet kernels provided an indirect method for investigating the way in which individual kernels absorb and exchange water, as this is a significant factor in tempering system selection.

Both systems increased individual kernel moisture content disparity immediately after temper. As temper time continued, this moisture disparity decreased. At 24 hours, the wet wheat had the same moisture disparity between kernels as that of the dry wheat when tempered with the intensive mixer. Wheat tempered with the conventional tempering screw, on the other hand, resulted in an increased moisture disparity of 11.2%.

Milling tests on the Miag Multomat experimental mill showed that the method of tempering had no effect on the percentage of flour yield nor its moisture content.

The intensive mixer gave lower cumulative percent ash and whiter flour color at 12 and 24 hours temper time. No significant differences in ash content or color were noted at 12 hours or 24 hours within a given tempering method.

The inconsistent trends of protein recovery, for either system was not conclusive.

The recovered dollar value of milled products per 100 lbs. of flour was higher for the intensive mixer by $0.093/cwt and $0.201/cwt at 12 and 24 hours respectively.